LONDON'S WATER SUPPLY

1903—1953

A Review of the Work
of the
Metropolitan Water Board

Issued by authority of the Board

W. S. CHEVALIER,
Clerk of the Board

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Preface

THIS book is issued by the Metropolitan Water Board to commemorate their Jubilee. Its purpose is to review the principal features of the undertaking since 1903, and to present to the reader a comprehensive picture of the work of the Board in supplying one-seventh of the total population of Great Britain with an abundant supply of pure and wholesome water.

I desire to express my indebtedness to my brother Chief Officers for their valuable contributions to the text, and to Mr. L. J. Flowerdew, B.Com., the statistical clerk, and Mr. G. C. Berry, M.A., Barrister-at-Law, research assistant, to whom I entrusted the onerous task of preparing the volume.

I also have the pleasure to express the Board's appreciation to Studio Egham, Sir William Halcrow & Partners, Mr. Eric Hosking, F.R.P.S., the London *Evening News*, and the Proprietors of *Punch*, for allowing the reproduction of certain of the illustrations.

W. S. CHEVALIER,
Clerk of the Board.

12*th February*, 1953.

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CHAPTER I

Historical Background

EARLY London, by reason of its geographical situation—on a broad river, fed by many underground streams—was well supplied with water. With the growth of the City and the disappearance of some of the original sources, however, it was necessary by the beginning of the 13th century to look beyond the City confines for adequate supplies.

In the year 1237 the City Corporation embarked on their first scheme for supplying the inhabitants of London by obtaining from Gilbert Sanforde, Lord of the Manor of Tyburn, liberty to convey water from the "town" of Tyburn into the city by pipes of lead. The site of the springs which furnished this water is now occupied by Stratford Place, Oxford Street. A conduit head for receiving and distributing the water was subsequently erected by the Corporation in Cheapside. During the following four centuries the City authorities, aided at times by charitable bequests, constructed and maintained several such conduits in different parts of the City. As the water, in general, had to be carried from the conduit head to the home a trade in water carrying grew up, although occasionally a "quill" was granted to certain influential people by means of which they were able to supply their houses from the conduit pipes.

Certain religious houses had their own conduit system. A 14th-century collecting chamber belonging to the Grey Friars system and removed from its position at the back of No. 20, Queen's Square, Bloomsbury, was re-erected on the site of the Round Pond at New River Head in 1927.

The Water Companies

The period of private water undertakings began in 1581 with the granting by the City Corporation of the use of the first arch of London Bridge to Peter Morris for a term of five hundred years. The arch was to accommodate a water wheel by means of which Thames water was pumped up into a tower

whence it was distributed by means of lead pipes into the houses in the eastern parts of the City. The supply so afforded was, however, of a local character.

In 1606 and 1607, the Corporation obtained two Acts of Parliament enabling them to construct a channel for bringing water from the springs of Chadwell and Amwell near Ware in Hertfordshire to the City. These powers they assigned to a private individual, Hugh Myddelton (created a Baronet in 1622), who completed the "New River," as it was called, in 1613. The "Adventurers" who had associated themselves with Myddelton were incorporated by Charter in 1619 under the name of the "Governor and Company of the New River brought from Chadwell and Amwell to London." Several small undertakings followed in and around London during the 17th and 18th centuries.

As a result of the rapid increase in building around London and the improvement in pumping machinery effected by James Watt, speculation in water supply sprang up, and between 1805 and 1811 five water companies were created by statute in the London area.

Parliament in those days approved of unfettered competition and with a view to encouraging it among the old and the new companies, the Acts under which the new companies were operated left their boundaries ill-defined so that in some cases the authorised area of supply of one company would overlap that of another. The result on the north side of the Thames was that in 1817, after a period during which water rates and charges were depressed to an uneconomic level, the companies arranged between themselves to operate only within agreed boundaries. The water rates were then raised, causing widespread dissatisfaction. This state of affairs led to the appointment of a Select Committee of the House of Commons to inquire into the state of the supply of water to the Metropolis.

In their short but interesting report of 1821 this Committee stated that they had found that a material improvement had taken place in the supply, both in respect of abundance and certainty, and that improved supplies had been extended to large districts in the neighbourhood of the Metropolis which were not before supplied. The Committee explained that:

"Competition, in ordinary cases, adjusts the supply to the demand

Sr HUGH MYDDELTON Knight & Baronet.

From an engraving by George Vertue, 1722
after the painting by Cornelius Jansen

MEMORIAL TO SIR HUGH MYDDELTON AT AMWELL

through the liberty which sellers have to go out of the market as well as to come into it: but in trades, carried on by means of large capitals, vested in fixed machinery and furnishing a commodity of no value but for consumption on the spot, the sellers are confined to the market by the nature of the trade; and if the newcomer has to seek immediate employment for large works, by taking custom from the established dealer, as there can be no great difference in quality of what they sell, they must vie in lowness of price and will probably be driven to underbid each other down to the point of ruin, because it is better to take anything than to take nothing for that which cannot be carried away: and this must go on until both are worn out, or one has out-lasted the others, and succeeded to a real and effective monopoly, or until by some arrangement between themselves they can put a stop to their mutual destruction."

Owing to the peculiar nature of water undertakings, therefore, the Committee found that:

"the principle of competition requires to be guarded by particular checks and limits in its application to them, in order to render it effectual without the risk of destruction to the competing parties, and thereby ultimately of a serious injury to the public."

The Committee recommended that a Bill should be introduced restraining the companies from advancing the rates beyond 25 per cent. above the old rates before the period of competition.

As the result of a considerable clamour directed against the quality of the water supplied by one of the companies, a Royal Commission was appointed in 1827 to inquire into the sources of London's water supply. This Commission were satisfied with the abundance of the water supplied but found that its quality required improvement and that many of the complaints on this account were well founded. They recommended that it should be derived from other sources and guarded by such restrictions as should at all times ensure its cleanliness and purity. Without entering into the question of the effects of the agreement reached by the companies on the north side of the Thames, the Commission observed that:

". . . if on the one hand, the preservation of the present Water Companies, from which the Public have undoubtedly derived immense benefits, would be endangered by unlimited competition with new companies that might be established for similar objects, it must, on the other hand be evident . . . that the constant and abundant supply of pure water is an object of vital and paramount importance to the inhabitants of this vast Metropolis, that the dispensing of such a

necessity of life ought not to be altogether left to the unlimited discretion of companies possessing an exclusive monopoly of that commodity; and that the interests of the Public require, that while they continue to enjoy that monopoly, their proceedings should be subjected to some effective superintendence and control."

Competition on the south side of the river did not cease until the 1840's.

With the absorption of the Hampstead Water Company by the New River Company in 1856 the number of companies serving the Metropolis was finally reduced to eight. These were:

On the north side of the Thames:

The New River Company (1619)
The Chelsea Waterworks Company (1723)
The West Middlesex Waterworks Company (1806)
The East London Waterworks Company (1807)
The Grand Junction Waterworks Company (1811)

On the south side of the Thames:

The Lambeth Waterworks Company (1785)
The Kent Waterworks Company (1809)
The Southwark and Vauxhall Water Company (1845). This was an amalgamation of two undertakings, the Southwark Water Company, incorporated in 1834, which had purchased an older undertaking of that name established about 1760, and the Vauxhall Water Company, incorporated in 1805.

Water supply and public health

Before coming to the efforts which were made during the second half of the 19th century to bring the water companies under single control, it will be well to refer briefly to the state of public health, in so far as it was affected by the water supply, at the beginning of the period.

It is not easy in these days to visualise the conditions of life in the large towns of England a hundred years ago. Industrial development had brought together vast numbers of people whose health and happiness were impaired by pitifully inadequate, and often incompetent, water supply arrangements. A Commission appointed to enquire into the State of Large

Towns and Populous Districts, in their Report of 1845 observed:

> "In addition to other causes of disease generally prevalent among the poorer classes of large towns, the almost universal scarcity of supplies of water for domestic use has been urged upon our attention as contributing in a very great degree to increase the evils under which they labour. It is difficult to estimate with any accuracy the influence produced on the health of the poor from this serious defect; but all those evils which have their origin in want of cleanliness must be greatly aggravated by this cause. The great moral results consequent upon an increase in the means of cleanliness have not yet, we fear, received the attention which their importance merits; the domestic comfort of a poor man's abode, and his own self-respect are mainly dependent upon this. We are convinced that their neglected condition is by no means the result of choice, although it may be the result of habit, produced by an unfortunate necessity.
>
> "It is not only for the more common description of household cleanliness that a better supply of water is required; its scarcity has hitherto prevented its use for many purposes, to which it can be most conveniently and economically applied."

and again:

> "The result of our enquiries has convinced us that much disease and many of the inconveniences under which the poorer classes labour, may be alleviated by a plentiful supply of this great necessity of life. All medical men unite in opinion of the great advantages that a better supply of water will effect in the health of the working classes."

In London the poor were without the advantage of water in their homes and had to fetch it from the communal standpipe in the usually filthy court or alley way. Or they could take their chance at the local pump which sucked water from easily infected shallow wells (some of them drained the cesspits and burial grounds). This water might be clearer than that supplied by the companies but it could be terribly treacherous. Dr. John Snow in 1854 proved that the clear waters of the Broad Street well, in Golden Square, Soho, were the cause of a local but appalling cholera epidemic.

The water supplied by the companies to the standpipes and to individual houses was only turned on for a few hours a day for anything between three and six days a week. The water had therefore to be stored and all types of receptacles were used for the purpose. In order not to miss the water when it came on taps were left open and much overflowing and waste resulted. This intermittent system of supply was favoured by the

engineers of the London water companies who could not then see how waste on a gigantic scale could be avoided if a constant supply of water were introduced throughout the Metropolis. They were quite unimpressed by local successes with constant supply in the provinces.

Having obtained the water somehow, it was open to the consumer to endeavour to purify it. The two largest companies (the East London and the New River), who obtained their supply from the Lee, supplied the raw material, merely purified by "deposit" in reservoirs. They were not afraid to extol the purity of their water. Before a Select Committee in 1851 the Engineer of the New River Company, then 70 years old and enjoying excellent health, assured incredulous Counsel that although he owned a filter, he drank a glass of New River water, unfiltered, every morning.

The social conditions obtaining in the City and the part played by water, or the lack of it, in contributing to them are graphically portrayed by Sir John Simon, Medical Officer to the City of London, in his Annual Reports of 1849 and 1853. He remarked on the intermittent system of supply:

> "I consider the system of intermittent water supply to be radically bad; not only because it is a system of stint in what ought to be lavishly bestowed, but also because of the necessity which it creates that large and extensive receptacles should be provided, and because of the liability to contamination incurred by water which has to be retained often during a considerable period. In inspecting the courts and alleys of the City, one constantly sees butts for the reception of water, either public, or in the open yards of the houses, or sometimes in their cellars; and these butts, dirty, mouldering and coverless, receiving soot and all other impurities from the air; absorbing stench from the adjacent cesspool; inviting filth from insects, vermin, sparrows, cats and children; their contents often augmented through a rain water pipe by the washings of the roof, and every hour becoming fustier and more offensive. Nothing can be less like what water should be than the fluid obtained under such circumstances."

In an eloquent appeal for improvements to be made in the living conditions of the poorer classes, he wrote:

> "I would beg any educated person to consider what are the conditions in which alone animal life can thrive; to learn by personal inspection how far these conditions are realised for the masses of our population; and to form for himself a conscientious judgment as to the need for great, if even almost revolutionary, reforms. Let any such person devote an hour to visiting some very poor neighbourhood in the Metropolis,

> or in almost any of our large towns. Let him breathe its air, taste its water, eat its bread. Let him think of human life struggling there for years. Let him fancy what it would be to himself to live there, in that beastly degradation of stink, fed with such bread, drinking such water."

During this period the relationship between an impure water supply and disease was practically unknown. It was believed that contagion was conveyed by the exhalations of the polluted atmosphere and this no doubt provided the motive for the construction of drains and sewers before the safeguarding of the water supply. It was permissible, and it later became compulsory, to drain houses into the sewers which themselves disgorged their contents into the tidal reaches of the River Thames. This meant that the danger of contamination of the river—already serious enough—was greatly increased.

It was against such a background that the pioneers of the public health services laboured. It was, in a sense, a corporate struggle, for the scientist, the medical man, the engineer, the surveyor, and the administrator, depended to a large extent upon each other for any measure of success attending their efforts. But the efforts and researches of the few specialists could not have exerted their full influence without the development of the social conscience of the people. Sir George Newman, a former Chief Medical Officer to the Ministry of Health (1919–1935), has said:

> "The advance in the public health of nations in modern as in ancient times has, however, been dependent upon the social evolution of man more than upon the growing knowledge of science. For progress must always draw its motive and energy from the aspiration and assent of the great mass of the people. The science of the few may indeed both lead and guide the will and habits of the people, but it cannot compel nor can it speedily change their tradition and custom."

But the first steps towards the purification of London's water supplies had already been taken, although in a small way. In January, 1829, the Chelsea Company had brought into use the first successful slow sand filter bed at their works off Grosvenor Road, designed by their Engineer, James Simpson. Since 1834 Parliament, too, had insisted on some of the companies making provision for the filtration of their river supplies when seeking to construct new works. In 1847 the Lambeth Company, who abstracted water from the Thames at what is now the site of the Royal Festival Hall, the furthest point downstream from

which water was then taken, decided on account of the filthy state of the river to apply to Parliament for powers to construct new works above the tideway at Long Ditton. The works were completed in 1852 and the relative immunity of this Company's consumers during the cholera epidemic of the following year proved the wisdom of their action.

At that time, however, the only object of filtration was clarification. Particles invisible to the naked eye were not thought of. The sand filtration process had been instituted but awaited the science of bacteriology to bring it to perfection.

Parliament and Water Supply during the second half of the 19th *Century*

During the second half of the 19th century increasing control was imposed by Parliament on the water companies whilst at the same time strenuous efforts were made to transfer their undertakings to a single body.

The General Board of Health in 1850 had recommended the consolidation of the management of the various works and their connection with works of drainage and sewerage. It further recommended that a constant supply should be introduced.

In 1852, the first Metropolis Water Act was passed. This was a most important step towards the provision of a better supply. Briefly, it prohibited the abstraction of water from the tidal reaches of the River Thames below Teddington Lock and imposed as a legal obligation the filtration of all river-derived water and the covering of all service reservoirs within a radius of five miles of St. Paul's. It also tried to make provision for compelling the companies to afford a constant supply, the conditions for which, however, were such as to render it ineffectual.

In 1866 the Richmond Commission was appointed "to enquire into the water supply of the Metropolis and the provision of water from distant sources." This Commission is particularly notable as being the first to consider the provision of a supply from Wales. However, it expressed satisfaction with both the quality and quantity of the supply from the Thames and Lee. It recommended that the undertakings of the several water companies should be transferred to a public body, and endorsed the recommendation of the Board of Health con-

cerning the provision of a constant supply. The Metropolis Water Act, 1871, provided the necessary machinery for introducing such a service but it took over 30 years to complete. This Act also provided for the appointment of an impartial Water Examiner who submitted monthly and annual reports to the Local Government Board on the metropolitan water supply together with reports by an analyst. He also made periodical inspections of the companies' works. Under the same Act a Government Auditor was appointed to report annually upon the companies' accounts.

Of the several attempts made to bring the water companies under one control, space allows only the briefest mention of the most important. In 1851, the Government unsuccessfully endeavoured to amalgamate the undertakings into one company. In 1878 the Metropolitan Board of Works introduced a Bill for their purchase. In 1880 a further Government Bill was introduced providing for purchase by a Water Trust by agreement with the companies, but a Select Committee appointed to consider the details, whilst approving the principle of public control, reported against the proposed terms of purchase. In 1891, the City and the Vestries both introduced Bills for transferring the water undertakings to Water Trusts. These Bills were referred to a Select Committee (the Ridley Committee) which reported adversely thereon, but recommended that the London County Council should be given authority to promote Bills for acquisition. This authority was obtained in the following year as a result of a Bill promoted by the City Corporation and the Council for constituting a new Body.

The London County Council came into existence in 1889 and from its earliest days showed great interest in the water question and embraced the policy of obtaining water from Wales. Armed with the above-mentioned authority, the Council sought repeatedly and unsuccessfully in the sessions of 1895, 1897, 1899 and 1900, to obtain powers to purchase the undertakings of the companies. The Government in the 1896 session also introduced the Metropolitan Counties Water Board Bill providing for a Water Trust composed of members nominated by the County Councils, the City Corporation and the Thames and Lee Conservancy Boards. After several modifications it was withdrawn.

During this last decade of the century two Royal Commissions were also appointed. The first, known as the Balfour Commission, was appointed in 1892 at the request of the London County Council and reported in 1893. It examined very thoroughly the whole question of the adequacy of existing sources to meet actual and anticipated requirements in the London area and came to the conclusion that these were likely to be sufficient for a period of 40 years provided adequate storage reservoirs were constructed. The Commission favoured the progressive construction of reservoirs in the Thames valley—a policy which has since been pursued by the Board.

The Llandaff Commission, 1897–1899

The last Royal Commission, appointed in 1897 and presided over by Lord Llandaff, dealt specifically with the question of control and also with intercommunication. Its final report, published in 1899, marked the closing of yet another chapter in London's water history and merits attention.

The Commission was appointed to enquire:

> "(1) Whether having regard to financial considerations and to present and prospective requirements as regards water supply in the districts within the limits of supply of the Metropolitan Water Companies, it is desirable in the interests of the ratepayers and water consumers in those districts that the undertakings of the water companies should be acquired and managed either:
>
> (*a*) by one authority; or
>
> (*b*) by several authorities; and if so, what should be such authority or authorities.
>
> To what extent physical severance of the works and other property and sources of supply of the several companies, and the division thereof between different local authorities within the limits of supply, are practicable and desirable; and what are the legal powers necessary to give effect to any such arrangements.
>
> (2) If the undertakings are not so acquired, whether additional powers of control should be exercised by local or other authorities; and, if so, what those powers should be.
>
> (3) Whether it is practicable to connect any two or more of the different systems of supply now administered by the eight Metropolitan companies; and if so, by whom, and in what proportion, should the cost of connecting them be borne, and what are the legal powers necessary to give effect to any such arrangement."

The Commission did not go into all the pros and cons of purchase of the water companies' undertakings but did examine at some length the problems likely to attend upon arbitration.

Nor did they re-open the questions dealt with by the earlier Balfour Commission. They accepted that Commission's findings as to the adequacy of the Thames and Lee for London's requirements, but in so doing they were obliged to go further and consider the cost of providing from these sources the additional supplies which would be necessary. The question of a supply from Wales, so strongly advocated by the London County Council, was discussed at length, but they decided that it would be unwise to cast aside the Thames and Lee as was the Council's intention. In their opinion:

> "To incur at once the far larger expenditure involved by the Welsh scheme . . . is needlessly to aggravate the financial difficulties which must attend the purchase of the water undertakings, and to throw an unnecessary burden on the present and next generation of water consumers and ratepayers and their immediate successors."

After examining in considerable detail the financial and other matters involved, the Commission concluded that, having regard to the magnitude of London's future water requirements, the concentration of the undertakings into the hands of one authority was desirable; that purity of supply, efficient distribution of available water and prevention of waste—arguments in favour of purchase—acquired additional importance as supplies increased; and that a public authority should be able to raise the large capital sums necessary in future at a cheaper rate than the companies could.

The Commission rejected the claim of the London County Council to be the purchaser and came to the conclusion that an entirely new authority was required. What that authority should be and how it should be constituted were, however, not easy questions to decide. With admirable candour they declared their appreciation:

> "of the great difficulty which exists in devising any Water Board, for the purpose of acquiring and managing the undertakings, which will be accepted by the various interests concerned and by Parliament."

On the question of the constitution of the proposed Water Board the Llandaff Commission stated:

> "We think the Water Board should be a permanent, and not a fluctuating body: consisting of not more than 30 members, selected on account of their business capacity and, if possible, their knowledge of matters connected with water supply, and so constituted as not to give a preponderance to any of the conflicting interests concerned.

"We think that the size and importance of the area to be dealt with takes the duties of the Water Board out of the category of purely municipal or local functions, and makes them a matter as much of national as of local concern. For this reason, we deem it necessary that the proceedings of the Board should be brought periodically and automatically under the observation of Parliament, and that it should include delegates of the Local Government Board, in order that the influence of the executive government should be continuously felt."

The suggested membership of 30 was arrived at as follows:

London County Council	10
Thames Conservancy	4
County Councils of Middlesex, Surrey, Essex, Hertford and Kent (two each)	10
Lee Conservancy Board	2
Borough of West Ham	2
Local Government Board ... ... (Chairman and Vice-Chairman)	2
	30

It was recommended that the Chairman and Vice-Chairman should receive adequate salaries; that members should be paid for attendances; and that they should hold office for a definite term of years.

The London Water Bill

As was perhaps to be expected, these proposals did not meet with unqualified acceptance. They were criticised on the grounds that the ratepayers throughout the water area were not all to be represented, whilst eight of the members would be unrepresentative persons; that a paid Board was undesirable; that the Chairman and Vice-Chairman, being salaried nominees of the Local Government Board, could not be expected to act impartially, and that the scheme was not based upon, nor tested by, evidence. There was considerable truth and common sense in these objections, and when the London Water Bill was introduced as a Government measure into the 1902 session of Parliament, it was evident that some regard had been paid to them. The Bill provided for a membership of 67 or 69 instead of the 30 suggested by the Commission. The London County

Council was to have appointed 10 members and the newly-created metropolitan boroughs 34.

It is interesting and instructive to recall some of the reasons advanced for the proposed constitution. The following are extracts from the Parliamentary Debates of the time:

". . . The Government plan has been to take the sanitary authorities of 'Water London' and make it their duty to select representatives, who will form the Water Board in future for London. The sanitary authorities which we selected are the Metropolitan boroughs and the City, the urban sanitary districts of the outside areas, the London County Council, and the County Councils of the adjoining Metropolitan counties. . . ."

"The County Councils of Kent, Middlesex, Surrey, Hertfordshire, and the Conservancies of the Thames and the Lee (will have) one (member) each."

The claims and responsibilities of the extra-metropolitan authorities were given weight:

". . . The authorities of the area outside London represent between one-fourth and one-fifth of the population affected. That population is growing very much faster than the population represented by the London County Council. These outside authorities have an especial interest in the matter, because the greater part of the water is drawn from the districts they represent and control."

". . . There are very many practical reasons why we cannot pass the outside authorities over. There are administrative reasons, and there are financial reasons. As a matter of administration, it would certainly not have tended to peace if they had given no representation on this controlling body to the authorities outside London. These are the road authorities, and this Water Board would have to interfere with their roads, and therefore it is only natural that they should be represented on the Water Board. But the financial difficulty is very much more serious. Supposing there is a loss in any one year that has to be made good by a rate; if the representation on this Board is confined to the County of London, what will happen? Either the Government must give to the London County Council rating power outside its own jurisdiction—and it will then have had to face the cry of the outside authorities that there ought, with proper management, to be no rate—or else they will have to allow the ratepayers of London to take the chance of any loss that may be incurred. The latter would at once ask why they should pay, and urge that all this loss came from supplying unremunerative districts. . . ."

Nor was the number of representatives arrived at without thought. Mr. Walter Long, President of the Local Government Board, said:

". . . I assure the House that the first step I took as the Minister

responsible for the preparation of this Bill was to obtain the advice of the most experienced expert connected with the administration of water in London—an expert of experts intimately acquainted with the whole area and knowing all the work that has to be done. I asked this expert to suggest to me what sort of body would have to be created, and the reply was 'a body that will have to appoint at least eight or nine separate committees, a body that will have to do the work now done by eight separate directorates numbering something like eighty or ninety gentlemen, and a body which will have to do work certainly as difficult and laborious as the work now done by the Metropolitan Asylums Board which numbers, I think, seventy-three' . . ."

The Bill was not to have an altogether easy passage through the House and met with considerable opposition from outside. The Press, naturally, had something to say about it. A periodical levelled these unflattering remarks at the proposals:

"The Local Government Board . . . like a bloated water spider, invites the flies into its parlour—or rather, would compel them; they are not to be 'may' but 'must' flies. But the precedent thus set, what is safe? What is to prevent a predatory body like the London County Council from acquiring by confiscation, supplemented by the high contingent liability on the rates, the gas works, the tramways, the omnibus lines, or solving the Housing Problem in the same easy way? . . . 'Free tram or bus rides,' 'free houses,' are no less catching cries to those upon whose shoulders the burden will not directly fall than 'free water'."

The Times, though far from being convinced, thought it the lesser of two evils:

"Most people who have given any attention to the subject are convinced that we shall probably be worse off than we are and certainly worse off than we might be were Parliament to supervise the existing companies as carefully as it watches railways. It may be asked why a purchase Bill is introduced at all in such circumstances. The answer is that it seems to be a necessary consequence of our political system that things shall be done from time to time which nobody really wants or really believes in. To be more specific, this Bill has to be introduced to put an end to a perpetual agitation which would otherwise culminate some day in a measure indefinitely worse. It is necessary to stop the scandalous waste of the ratepayers' money and of Parliamentary time and temper involved in the annual promotion of Water Bills by the London County Council."

No less a figure than Mr. John Burns had misgivings about the proposed Board and urged that control should be in the hands of:

"An efficient and experienced and a centralised body such as the London County Council is, and a Water Committee of not more than

> 15 or 20 at the outside would manage the affairs of Water London infinitely better than this mob, for such it is, of 67 or 69 men gathered from all the corners of the earth, knowing as much of London water as I do about the Zimbabwe temples north of Rhodesia."

and again:

> "This body will not work; it is irresponsible and I believe that it will prove to be incompetent. It will rely upon the Chairman and Deputy Chairman for its advice and guidance and they, poor fellows, will probably break down."

But John Burns did not foresee that he was to be one of the first members of the Board and one of its first good friends. As President of the Local Government Board, too, from 1905 to 1914 in the Campbell-Bannerman and Asquith administrations, he paid handsome tributes to the Board's administration and achievements. Sir Melvill Beachcroft, as Chairman of the Board, later bore testimony to Mr. Burns's contribution to and valiant support of the Board during its early struggles.

The Bill was fully investigated, and after some amendment became law on 18th December, 1902, as the Metropolis Water Act, 1902. The new Board met for the first time on 2nd April, 1903.

Section 37 of this Act fixed 24th June, 1904, as the "Appointed Day" for the Board to take over the undertakings of the water companies, but the Local Government Board, under powers vested in them by the Act, postponed the appointed day in the case of the New River Company to 25th July, 1904.

CHAPTER II

Constitution and Administration

THE Metropolis Water Act, 1902 provides for 66 members of the Board appointed by authorities, generally referred to as constituent authorities, consisting of (1) single bodies and (2) grouped councils acting through joint committees in the appointment of a single member of the Water Board to represent each group of councils. A list of these authorities and the names of their present representatives will be found in Appendix A.

The Chairman and Vice-Chairman of the Board need not be appointed from among the members although, as to fact, they always have been.

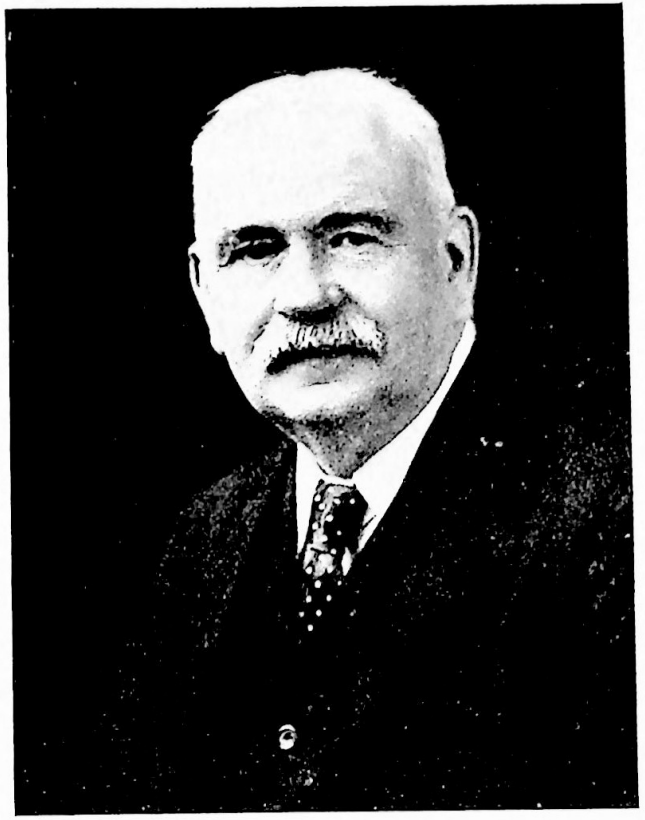
The normal term of office of the Chairman, Vice-Chairman and members of the Board is three years. The first Board went out of office in June, 1907. During the first World War the three-year provision was waived and the fourth Board which took office in June, 1913 continued until June, 1919. When the Representation of the People Act, 1948, came into force in 1949, the period of office of the fourteenth Board was extended by Order from June to November so as to overcome certain difficulties arising from the changed dates of election of local Councils. In 1952 a further Order was obtained which extended the term of office of the fifteenth Board from June, 1952 to November, 1953 and at the same time changed the date of appointment of members from June to November in every third year thereafter. The present Board will, therefore, go out of office on 1st November, 1953.

The representation of authorities on the Board still stands as prescribed by the Act of 1902 but alterations have been made from time to time in the grouping of the constituent authorities comprising the Joint Committees of Election, as a result of changes in the boundaries and status of some of the authorities concerned. Suggestions have been made at various times that the constitution should be varied so as to reflect current

SIR EDMUND BARNARD, O.B.E., M.A., D.L.
Chairman, 1908–1920

SIR MELVILL BEACHCROFT
Chairman, 1903–1908

LT.-COL. J. B. P. KARSLAKE, T.D., M.A., F.S.A.
Chairman, 1920–1922



SIR CHRISTOPHER MUSGRAVE
Chairman, 1922–1928

COL. SIR WILLIAM PRESCOTT, BT., C.B.E.
Chairman, 1928–1940

HENRY BERRY, ESQ., C.B.E.
Chairman, 1940–1946

HAROLD GIBBONS, ESQ., O.B.E.
Chairman, 1946-1948

WILLIAM H. GIRLING, ESQ., O.B.E.
Chairman, 1948-

conditions more closely, particularly having regard to changes in population and rateable value within the area. Whether any changes should be made is a matter of policy and it is not the purpose of this Review to examine the subject.

Once appointed to the Board, members seem reluctant to sever their connections with it, as is evidenced by their periods of office. Not a few have served for many years and there are some whose service extends over two decades or more. Amongst the present members the names of Mr. Henry Berry, C.B.E., M.I.Mech.E., A.I.Struct.E., who will complete 30 years' continuous service in 1953 and who was Chairman from 1940 to 1946 comprising the difficult war years, Mr. W. H. Girling, O.B.E., the present Chairman, who first came to the Board in 1920, and Mr. J. H. MacDonnell whose association also goes back intermittently to 1920, are worthy of mention. The blue riband for unbroken service is held by a former member and Chairman, Lt. Col. J. B. P. Karslake, T.D., M.A., F.S.A., D.L., J.P., who was appointed to the first Board in 1903 and at the time of his death in September, 1942 had completed nearly 40 years' service. Major Sir Patrick B. Malone, J.P., an original member, served continuously until 1937. Mr. Henry Ward, J.P., M.I.C.E., whose name was associated with the London County Council's proposals for a supply from Wales, was also an original member and had attained over 30 years' service at the time of his death in March, 1936. It is pleasing, too, to record that Mr. Christian C. T. Doll, M.A., F.R.I.B.A., and his late father Mr. Charles FitzRoy Doll, F.R.I.B.A., have between them served since 1903, except for one short break.

There is something of more than passing interest in such records. They bear witness to the wealth of interest and fund of knowledge relating to the Board's work possessed by the members, which have been invaluable when from time to time the need for them has arisen.

Under the Act of 1902 the Board are empowered to pay their Chairman and Vice-Chairman such salary or salaries as they think fit, but no such payment has ever been made. An allowance is granted to the Chairman in respect of official hospitality.

It was not until 1937 that the first lady member, Mrs. Eleanor Nathan, M.A., J.P., (later The Rt. Hon. Lady Nathan

of Churt) came to the Board. Since then the following have also been appointed, namely, Miss Barbara Betts (Mrs. Barbara Castle, M.P.), Mrs. Lilian Bryant, J.P., Mrs. E. V. W. Deakin, Mrs. J. W. Field, J.P., Mrs. M. M. Paterson, J.P., Mrs. Jessie Burgess, J.P., and Mrs. E. M. Newman, O.B.E. The last two named are present members, Mrs. Burgess being Vice-Chairman of the Finance Committee and Mrs. Newman, Vice-Chairman of the Water Examination Committee.

Many notable people have served as members of the Board. They include Sir Ion Hamilton Benn (the only original member still living), Sir Melvill Beachcroft, Lord Welby, Sidney Webb (Lord Passfield), John Burns, Mr. A. Creech Jones, the Marquess of Aberdeen, Mr. Herbert Morrison, M.P., and the Viscount Falmouth (a present member). Others, perhaps less well-known, have also made their contribution to the stability and progress of the undertaking which it is the purpose of this Review to record. And here it is appropriate to remark that membership, particularly the Chairmanship of the Board or of the Committees, is a responsible task. Chairmen of the Board and other members have been called upon to give evidence before Courts of Inquiry and Departmental or Parliamentary Committees on important matters involving mastery not only of general principles of administration but also of their detailed application (as, for example, the Court of Arbitration, 1903, the Charges Bill, 1906, the Monro Inquiry, 1920, the Departmental Committee on Greater London Water Supplies, 1947). Appearance before such Committees, sometimes involving cross-examination by learned Counsel, can be a very searching and exhausting experience even for the technical expert.

Distinguished visitors have honoured the Board on many occasions by their presence at meetings or by visiting the works. His Majesty King George the Fifth, accompanied by Her Majesty Queen Mary, inaugurated two of the largest reservoirs in 1913 and 1925. His late Majesty King George the Sixth, accompanied by Her Majesty Queen Elizabeth the Queen Mother, performed a similar ceremony informally at Staines in 1947. His Royal Highness the late Duke of Kent, K.G., paid a visit to the Head Offices and the works in the Thames valley in 1940. Ministers of the Crown, civic dignitaries and many

others, including visitors from overseas, have graced the meetings of the Board from time to time. These visits are appreciated by members and are also, one might say, a tribute to the great Undertaking which serves 6½ million persons—more than one-seventh of the combined population of England and Wales.

Nor do the Board fail to welcome others who have no such claim to fame or high office. For example, a district foreman who, during the earliest days of bombing in 1940, showed exceptional courage and devotion to duty in spite of personal suffering; a filter bed labourer who rescued a small boy from drowning in the River Lee in 1949; another employee who was about to retire after 50 years' service with the Board and one of their predecessors—these and many like them have found that the members sitting in session at New River Head are not an impersonal and detached machine, but are a body of men and women of dignity and understanding.

The Board normally meet in the afternoon of every fourth Friday except during recess. The fine Board Room on the first floor seems to lend tone to their proceedings. With some regard for history, the walls of the Board Room are flanked with reproductions of the seals of the eight metropolitan water companies—a reminder both of the continuity of the water service over the centuries and of the essential unity of the Board. The meetings are open to the Press and public.

Committees

The actual administration of the Board's work is referred to Committees, the origin, growth and present duties of which are of some interest.

Three Committees were set up at the second meeting of the Board, on 23rd April, 1903, as follows: (i) Finance Committee (16 members), a statutory Committee under the Act of 1902, to exercise the powers and duties prescribed by section 20 of that Act, (ii) Law and Parliamentary Committee (22 members) charged with all legal and Parliamentary business, including the preparation and conduct of the Board's case for arbitration then pending, and (iii) General Purposes Committee (22 members) to deal with all matters not coming within the

province of the other Committees, including control of the staff and accommodation.

Of the matters which required consideration at that time, that of the Arbitration proceedings overshadowed the rest, and in order to deal with it effectively it was decided in May of that year to set up a special Arbitration Committee to which was transferred this part of the duties of the Law and Parliamentary Committee.

The responsible nature of the work falling to these Committees was enhanced by the fact that many of the problems confronting them were without precedent in water history.

The imminent transfer of the several water undertakings, with their scattered works, offices and staff, caused the Board in November, 1903, to consider the question of the appointment of Committees for their management. They adopted the guiding principle that all the undertakings should be brought under central control and be administered as one whole. This end was to be achieved by dividing the business of all the undertakings into classes and entrusting each class to a Committee appointed for the purpose, thereby securing uniform treatment throughout the area.

A Works Committee consisting of 24 members was thereupon appointed to consider all questions relating to the sources of supply, distribution of water and the management of the works generally. The three earlier Committees were also reconstituted with slightly different membership and additional duties. The Finance Committee was to superintend the collection of water charges and the Law and Parliamentary Committee was given charge of matters relating to the assessment of the Board's property for rating and taxing purposes. The General Purposes Committee was to consist of one representative nominated by each of the three Committees abovementioned, together with 12 other members to be appointed by the Board.

The Board were anxious that each of the members should be given an opportunity to serve on a Committee of his own choice and the Clerk of the Board was accordingly instructed to ascertain each member's wishes in that respect—a principle which still obtains. The first Special Committee of Selection met and reported to the Board in December, 1903, when it was

evident that most members desired to serve on at least one of the standing Committees. The membership of the Works Committee was accordingly fixed at 27, that of the Finance Committee at 18 and that of the Law and Parliamentary Committee at 15.

They were not, however, to remain so for long. In June, 1904, acting on the advice of the Clerk of the Board and the Accountant, it was decided to appoint an Appeal and Assessment Committee "to consider all questions relating to the assessment of water charges and appeals against such assessments." This new Committee consisted of 12 members and the membership of the others was slightly reduced. The title of the Works Committee was changed to that of Works and Stores Committee.

During those early months there were no official Orders of Reference to the Committees, although the general scope of their activities was fairly clearly defined. By the end of 1904, however, Orders of Reference to the standing Committees had been approved by the Board.

At first the duty imposed on the Board by the Act of 1902 to "cause to be made chemical and bacteriological examinations and experiments as to the condition of the water to be supplied by the Board, and to supply such buildings, apparatus and plant and such staff and construct such works as may be required for enabling such examinations and experiments to be conducted efficiently" fell to the Works and Stores Committee. In 1905 the Board decided to erect a central laboratory and to appoint a Director of Water Examination, and later in that year followed up this action by the appointment of a Water Examination Committee (consisting of 7 members) to deal with this aspect of their functions.

The usually harmonious relations between Committees were somewhat disturbed towards the end of 1909 over the question of which Committee should settle claims for compensation due to burst mains. The matter was resolved by the Board at their meeting in February, 1910, by the appointment of a Claims Committee to consist of the Chairman and Vice-Chairman of the Board, the Chairman and Vice-Chairman of the Works and Stores Committee and the Chairman and Vice-Chairman of the Law and Parliamentary Committee. The general principles to govern the settlement of claims were laid down at

the same time and remained operative until Orders of Reference were approved in May, 1913. Many years later, in 1940, it was decided that since both the Appeal and Assessment and the Claims Committees could be said to act in a quasi-judicial capacity as between the Board and the public, one in regard to appeals against water rates and charges and the other in regard to claims for compensation for damage, they should be amalgamated under the title of the Assessment and Claims Committee.

Reference is made elsewhere to the appointment in 1921 of the Advisory Joint Committee of Members and Officers. An Appeals Committee, consisting of the Chairman and Vice-Chairman of the Board and not more than five other members, to consider appeals of officers and employees from decisions of the administrative Committees, was established in 1940.

Before leaving this branch of the subject, a word should perhaps be added concerning the appointment of special committees and of sub-committees.

It is, of course, inevitable that matters arise from time to time which do not fall within the specific terms of reference of an existing Committee or which for some other good reason require special consideration. For such, a Special Committee is appropriate. Its constitution and terms of reference are governed by the circumstances of each case, but it is usual for such a Committee to report its proceedings directly to the Board. Among the more important have been those on Administration and Future Supplies. There is at present in being a Special Committee on Civil Defence appointed in 1950.

Committees have power to appoint sub-committees as necessary, and in former days this practice was more extensively used than it is to-day. There are now sub-committees of the Finance and the Works and Stores Committees only.

Financial Control

The exercise of financial control is an important part of administration. It is, in general, performed through the Finance Committee, which as already remarked is established under the Act of 1902. A principal feature of the system is the submission to the Board of annual estimates of income and

BOUNDARY OF AREA SUPPLIED BY METROPOLITAN WATER BOARD

AUTHORITY APPOINTING TWO REPRESENTATIVES

AUTHORITY APPOINTING ONE REPRESENTATIVE

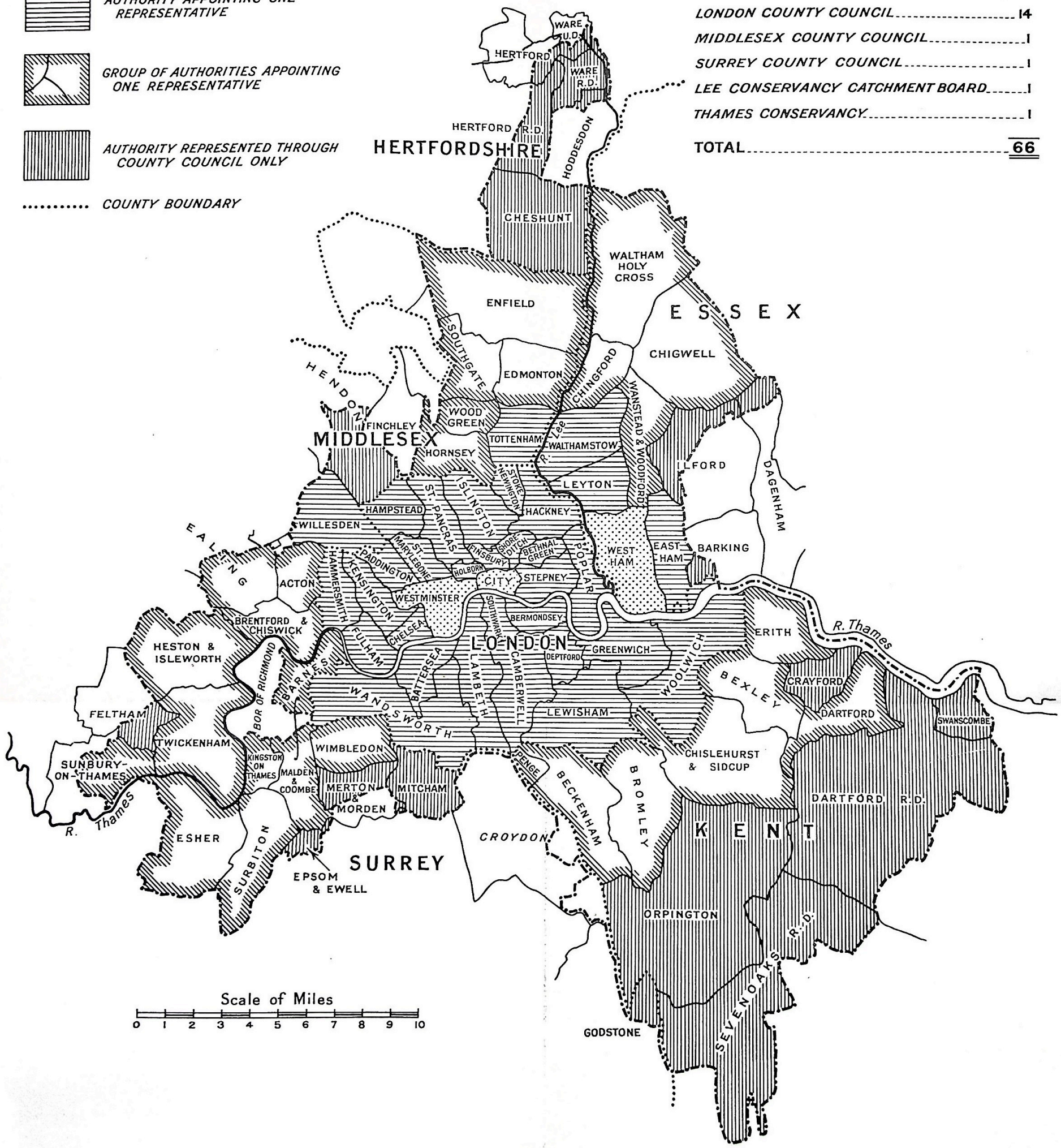
GROUP OF AUTHORITIES APPOINTING ONE REPRESENTATIVE

AUTHORITY REPRESENTED THROUGH COUNTY COUNCIL ONLY

COUNTY BOUNDARY

NUMBERS OF REPRESENTATIVES FROM CONSTITUENT AUTHORITIES

LOCAL AUTHORITIES	45
ESSEX COUNTY COUNCIL	1
HERTFORDSHIRE COUNTY COUNCIL	1
KENT COUNTY COUNCIL	1
LONDON COUNTY COUNCIL	14
MIDDLESEX COUNTY COUNCIL	1
SURREY COUNTY COUNCIL	1
LEE CONSERVANCY CATCHMENT BOARD	1
THAMES CONSERVANCY	1
TOTAL	66



Scale of Miles

0 1 2 3 4 5 6 7 8 9 10

MAP SHOWING REPRESENTATION OF AUTHORITIES ON THE BOARD

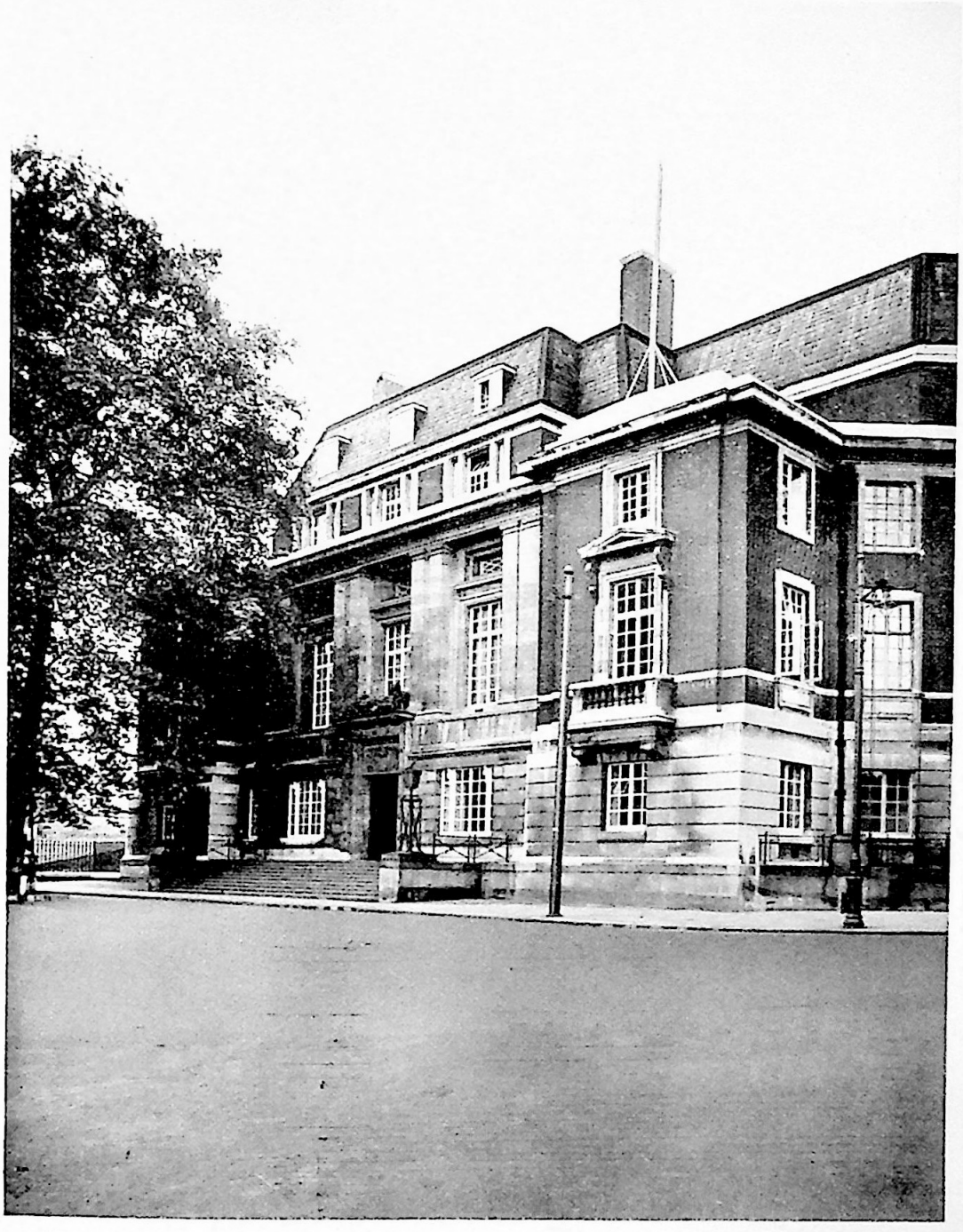
Committee consult the Treasurer and Comptroller on the financial implications of a proposal, and so on.

This underlying and essential unity of the Board carries with it a measure of departmental interdependence which it is probably true to say is greater today than ever before.

During the course of subsequent chapters the responsibilities and duties of the various chief officers will become apparent, but it is appropriate in this chapter on administration, to remark briefly on the functions of the Clerk of the Board.

The precise duties appertaining to the Clerk are not easily described, but the broad pattern is clear.

The Clerk is implicit in the whole system. Without him the Board could not function as a coherent body. He is Clerk of all Committees and is responsible for issuing summonses to meetings, recording their proceedings and issuing their instructions. He is the officer to whom the Chairman and the Committees look for advice on matters likely to affect more than one department. It is the Clerk whom the members and other Chief Officers consult on interpretation of the standing orders and internal regulations. Even after 50 years matters still arise which call for the frequent exercise of this quasi-judicial function. The Clerk is the official mouth-piece of the Board. In relation to other Chief Officers he exercises important administrative and co-ordinating functions and in relation to outside bodies—Government departments, local authorities, public utilities and the like—he is the normal channel of communication on matters of principle. The Clerk is responsible for advising the Board on, and for carrying out arrangements in connection with, all their functions and ceremonies.



THE BOARD'S HEAD OFFICES
NEW RIVER HEAD, LONDON, E.C.1

THE OAK ROOM

CHAPTER III

New River Head and Coat of Arms

In July, 1913, the Board decided to erect their central office on a portion of the property in their possession at New River Head, Rosebery Avenue, in the Borough of Finsbury. An alternative site near Holborn and overlooking Gray's Inn Gardens was submitted to the Board at the same time but was rejected. The site chosen is an important one as far as the history of London's water supply is concerned as it covers the Round Pond constructed by Sir Hugh Myddelton to receive the waters of the New River. The Board further decided that the Oak Room from the old "Water House" at New River Head should be incorporated in the new building. This room, also referred to as the Court Room, had been used for meetings of the New River Company's directors. Its black oak-panelled walls are decorated with fine wood carvings, attributed to Grinling Gibbons, and contain a panel of the arms of King William III, whose painted portrait appears in the centre of the richly moulded ceiling. In the ceiling also are reproduced the arms of Sir Hugh Myddelton and the Grene family. John Grene married Sir Hugh's grand-daughter Elizabeth and in 1667 became Clerk to the New River Company. It has been assumed that it was he who ordered the scheme of decoration. The Board purchased the room from the New River Company in February, 1904, for £2,000. It is now insured for the sum of £24,000.

Mr. E. Guy Dawber, the Assessor nominated by the President of the Royal Institute of British Architects to advise on the designs for these new offices, submitted in a competition, reported in favour of that of Mr. H. Austen Hall, F.R.I.B.A. and his recommendation was approved by the Board in May, 1914. On

27th November, 1914, the Board accepted the tender of Messrs. T. W. Heath & Son, amounting to £110,004 for the erection of the building, and on 21st July, 1915, the foundation stone was laid by the Chairman of the Board, Mr. E. B. (later Sir Edmund) Barnard, O.B.E., M.A., D.L.

Labour troubles and other difficulties prevented Heath & Son from observing certain conditions of the contract which was taken over by Messrs. Rice & Son on 1st October, 1915, at the revised figure of £114,136. On 23rd June, 1916, work on the building was suspended by order of the Ministry of Munitions, and under the terms of a settlement approved by the Board, in May, 1918, the original contract was cancelled. The work was recommenced in January, 1919, the new contract with the same parties providing for the work to be completed within a year. The Offices were formally opened by Mr. Barnard on 27th May, 1920, and the Board held their first meeting in the new building on 2nd July, 1920.

A floor was added to the building in 1934-36 in order to provide accommodation for the increasing number of clerical staff necessitated by the continued growth of the Board's business. In 1947 a large temporary drawing office was erected on the site of one of the disused filter beds adjacent to the offices, to house some of the technical staff.

The establishment at New River Head of the laboratories for the Water Examination department is described more fully elsewhere (see page 237).

The Board's Coat of Arms

In July, 1929, the Board decided to apply to the College of Arms for a Grant of Arms, and in March, 1931, received the appropriate documents.

The following is a description of the Arms:

> *The Blazon.*—Argent on a Pile vert a dexter Hand Or issuing from a Cloud in chief proper and scattering eight Gouttes d'eau in base three Bars wavy Azure on a Chief nebuly of the first a Cross of Saint George charged with a Lion of England, And for the Crest on a Wreath of the Colours a Roundel charged with a Hand issuing from a Cloud and scattering Gouttes as in the Arms.

The Supporters.—On the dexter side a figure representing Hygeia vested Argent mantled Azure and on the sinister side a figure representing Aquarius habited Azure.

The Motto.—Et plui super unam civitatem.

The first consideration that presented itself in considering the design was that there should be a definite reference to Sir Hugh Myddelton, the Projector of the New River, whose Arms were a pile vert on a field argent charged with three wolves' heads erased of the field, i.e., three silver wolves' heads on the pile vert, as shown on the ceiling of the Oak Room at New River Head. The original Arms borne by him were those of the Myddelton family, namely, a bend vert on a field argent, but Sir Hugh changed the bend for the pile in 1622 in memory of this undertaking. The other branches of the Myddelton family bear the original Arms. The pile therefore has definite reference to water engineering.

To provide a substitute for the three wolves' heads, an appropriate piece of symbolism was found in the seal of the New River Company. This seal was cut in 1619 by "Mr. Hole"—presumably William Hole, an engraver, of the early 17th century—who was paid £8 for his work and for the silver which he used. It depicts a Hand issuing out of the clouds throwing down rain upon the City of London. The seal also shows St. John's Gate and Old St. Paul's without the wooden steeple, which was burnt down in 1561 and never re-erected. The cathedral itself was destroyed in the Fire of London, 1666. This seal suggested that one of the principal features of the Shield could appropriately be a Hand issuing from a heraldic representation of the clouds, throwing down rain.

London's water supply has been honoured from the time of King James I with Royal recognition. (Stow states that Henry III assisted the City in acquiring land and water rights for the first conduit, 1237.) The Chief, or top of the Shield, is therefore occupied by the Cross of St. George charged with the Lion of England. The chief adopted is nebuly, that is one with an indented edge which is heraldically supposed to represent the edges of clouds as drawn by medieval artists. It was necessary to obtain the Royal Warrant granting to the Board His Majesty's Royal Licence and Authority to bear this particular

feature (the Cross of St. George charged with the Lion of England).

The Base of the field is charged with three bars wavy, representing water, as the sources of the Board's supply are found in the rivers and the wells.

The Chief and Base together associate the Coat with that of the London County Council, the principal constituent authority of the Board.

The Crest or Badge is taken from the principal feature of the Shield, namely, the Hand Or issuing from the clouds and throwing down rain. It is placed in a roundel of blue colour (technically called a Hurt), so that the full Crest shows the Hand issuing out of the clouds and sky, throwing down rain; the eight drops representing the eight Companies. The roundel may also be regarded as representing the Firmament.

The motto adopted is that which appeared on the seal of the late New River Company, namely;—

"Et plui super unam civitatem."

("And I caused it to rain upon one City").

The word "civitatem" means city, or state, or community; and the Board may be regarded as a united community for one specific purpose.

The motto itself is taken from the Latin Vulgate, being part of Verse 7 of the Fourth Chapter of Amos, as follows:—

> "7. Ego quoque prohibui a vobis imbrem, cum adhuc tres menses supressent usque ad messem, et plui super unam civitatem, et super alteram civitatem non plui; pars una compluta est, et pars super quam non plui, aruit."

The translation in the authorised version is as follows:—

> "And also I have withholden the rain from you, when there were yet three months to the harvest; and I caused it to rain upon one city, and caused it not to rain upon another city; one piece (part) was rained upon, and the piece (part) whereupon it rained not withered."

The Supporters were suggested by the seals of the late Metropolitan Water Companies, namely, the classical figure of Hygeia, the Goddess of Health (taken from the seal of the Grand Junction Waterworks Company), on the dexter side, and that of Aquarius, the Waterbearer (or indifferently the River-God) on the sinister side. This figure appeared in the seals

of the East London Company (1807), the Chelsea Company (1723), the Lambeth Company (1785), and the West Middlesex Company (1806). Thus the Crest and Supporters directly refer to six of the eight Companies. The Supporters are depicted as standing on a "platform" of ground proper on which the rain is falling.

The Coat of Arms has thus the following features:—

(*a*) It is symbolical of Water Supply.

(*b*) It has direct association with the old New River Company and Sir Hugh Myddelton.

(*c*) The Chief gives it specific Royal association which the history of London's water supply undoubtedly warrants.

(*d*) The Chief and Base also have direct association with the County of London.

(*e*) The Supporters are associated with five of the other Metropolitan Water Companies.

(*f*) The Crest or Badge is symbolical and readily reproducible.

CHAPTER IV

Early Days

1903–1910

Six days after the Metropolis Water Bill had reached the Statute Book, that is on the 24th December, 1902, the Local Government Board issued an Order to those constituent authorities who were to have direct representation on the Board, giving instructions for the appointment of members. On 9th January, 1903, a similar Order was sent to the grouped Councils, who were to be represented by members appointed by Joint Committees of Election, concerning the constitution of the several Joint Committees and the appointment of their members. Appointments under these two Orders were notified to the Local Government Board.

By 12th March, 1903, all the members had been appointed and the Local Government Board therefore issued an Order on that day to the members of the Water Board summoning them to the first meeting to be held at the Council Chamber of the Privy Council on Thursday, 2nd April, 1903, at three o'clock in the afternoon.

In pursuance of the Order of the Local Government Board the Chair was taken by Mr. Almeric William FitzRoy, C.V.O., Clerk in Ordinary to the Privy Council, who welcomed the members and invited them to elect a temporary Chairman. Sir James Thomson Ritchie, a representative of the City of London, was thereupon appointed.

An adjourned meeting of the Board was held on 23rd April, 1903, at Caxton Hall, Westminster, and a further adjourned meeting on 30th April, 1903, at the office of the Metropolitan Asylums Board on the Victoria Embankment, on the site now occupied by New Carmelite House. At this last meeting, Mr. R. M. (later Sir Melvill) Beachcroft, a representative of the London County Council, was appointed Chairman. The office of Vice-Chairman of the Board was not filled until 29th

April, 1904, when Mr. John Glass, the representative of the Stoke Newington Borough Council, was appointed.

From 30th April, 1903, until 10th May, 1918, the meetings of the Board continued to be held at the office of the Asylums Board. Subsequent meetings were held at Armfield's Hotel, South Place, Finsbury, until the Board's head offices at New River Head were opened in May, 1920.

For the first few weeks meetings of the Board were held weekly, but on 15th May, 1903, when the first Standing Orders were adopted, it was laid down that meetings should be held at 2.30 o'clock in the afternoon of Friday in each alternate week unless otherwise ordered. This rule remained in force until 1st August, 1909, when the present regulation which provides for meetings to be held on Friday in every fourth week unless otherwise ordered, was substituted.

It needs to be emphasised that, although the new Board was in being and functioning for the greater part of the year 1903, the actual transfer of the companies' undertakings with their staffs and offices did not take place until the middle of the following year. There was therefore a period of overlapping administration—a period of preparation—to be followed after the appointed day by centralisation and the beginnings of unification. This process, which involved also the appointment of Chief Officers and the setting up of departments, occupied several years but by 1909–10 the broad pattern of the organisation had taken shape.

In tracing the sequence of principal events some licence will be taken at the expense of chronology. It is thought that, in this case, the end will justify the means.

One of the first matters to be considered was the appointment of a Clerk of the Board. Owing to the fact that the officers and servants (as they were then called) of the water companies would shortly be transferred, the Board in 1903 were not called upon to appoint an extensive staff, but the position of Clerk had to be filled immediately. As a temporary measure the Board had, at their first meeting, appointed Mr. A. V. (later Sir Aubrey) Symonds of the Local Government Board to act in that capacity.

Applications for the position were invited in the public press. One hundred and twenty-one were received and after careful examination three names were submitted to the Board on

22nd May, 1903, namely Mr. George W. Clarke, Town Clerk of Stepney, Mr. Albert Bamford Pilling, Town Clerk of Devonport and Mr. William Terrey, General Manager of the Sheffield Corporation Waterworks. Only Mr. Pilling and Mr. Terrey appeared at the meeting when on a show of hands Mr. Terrey was appointed. Mr. Terrey subsequently withdrew his candidature and on 12th June, Mr. Pilling and two other candidates appeared before the Board. The choice fell on Mr. Pilling who thus, at the then comparatively early age of 39 years, began a period of service, the influence of which has become almost legendary.

Arbitration

The newly-created Board were at once confronted with what was probably the biggest arbitration on record at the time and this task overshadowed all others during their first year of office.

On the advice of the Law and Parliamentary Committee, who had been appointed to deal with all legal questions, the Board, on 29th May, 1903, appointed a special Arbitration Committee to conduct their case.

Acting on this Committee's instructions, the Board's Solicitors, Messrs. Linklater, retained the following Counsel:

Mr. Fletcher Moulton, K.C. (later Lord Moulton), The Hon. J. D. Fitzgerald, K.C., Mr. G. M. Freeman, K.C., Mr. Honoratus Lloyd and Mr. A. B. Shaw.

Sir Alexander Binnie, a former Chief Engineer of the London County Council, who had been responsible for the Council's Welsh water supply scheme, Mr. G. F. Deacon of "Deacon meter" fame, and Mr. E. Brough Taylor advised the Board on engineering matters.

The companies on their side, apart from retaining the services of eminent counsel and professional witnesses, also had the advantage of the accumulated knowledge of their officers upon which to draw.

The Court of Arbitration consisted of three Commissioners : The Rt. Hon. Sir Edward Fry, a retired Lord Justice of Appeal, Sir Hugh Owen, G.C.B., a retired permanent Secretary of the Local Government Board, and Sir John Wolfe Barry, K.C.B.,

a Past-President of the Institution of Civil Engineers and Engineer of the Barry Docks and Tower Bridge.

The proceedings opened on 26th October, 1903, at the Institution of Mechanical Engineers, Storey's Gate, and a total of over 70 sittings were held.

The authority of the Court was defined by the 1902 Act to extend to the settlement and determination by them on such terms and in such manner as was "most just and fit" of the matters referred to them, and also of all matters and questions incidental thereto. The only appeals allowed from the decisions of the Arbitrators were those upon questions of law arising in the course of the proceedings.

The Act further provided that in fixing the sum to be paid by the Water Board, the Court should determine the value of the undertaking of each metropolitan water company as if, with the necessary modifications, the law of compensation for the purposes of the Lands Clauses Act were applicable to the case, but no allowance was to be made for compulsory sale, nor were the arbitrators to take into account any enhancement or depreciation of the market value of the stock or shares of the company which, in the opinion of the Court, was caused by the passing or the anticipation of the passing of the Act. The Court were allowed to make in their awards such allowance as they thought fit for any loss of interest pending re-investment and the cost of re-investment and for recovering any costs which had been, or were likely to be, incurred in consequence of the passing of the Act by any metropolitan water company, or the share- or stock-holders therein, which the Court considered should be borne by the Board.

During the course of the arbitration several questions of law arose, particularly in the case of the New River Company. Four of these points were eventually taken to the House of Lords who decided in the Board's favour. These related to the limitation of dividends, the profits from the Company's lands which were not to be transferred, payments made in respect of Land Tax and certain Sinking Fund Clauses. The Company had claimed that the profits derived from their undertaking were not limited to ten per cent. of their capital as provided for by certain sections of the Waterworks Clauses Act, 1847, incorporated in the Company's Act of 1852, because of a saving

clause contained in this latter Act. It was held, however, that this saving clause had no effect as far as the limitation of dividends was concerned.

The value to the ratepayers of this decision of the House of Lords was forcibly illustrated by the fact that after the Court of Arbitration had delivered, in the Board's favour, their decision on the question, the Company submitted an amended claim calculated on that basis, amounting to £8,214,163, a reduction of £5,045,981 on their claim of £13,260,144.

The claims of the water companies amounted in all to £50,939,898. The Court awarded £30,662,323 in cash in respect of the transfer of the undertakings, to which sum a number of other items had to be added, bringing the total cost of acquisition to some £46,939,258. It is clear that a substantial sum for the goodwill of the undertakings was included, for whereas at the appointed days the capital expenditure of the companies was approximately £22,900,000, the cost of acquisition was, as just stated, £46,939,258. It should be added that whilst this great increase in the nominal capital of the Board as compared with that of the companies may be regarded simply as the result of the conversion of stocks bearing fluctuating dividends and differing rates of interest into stock carrying a fixed interest of three per cent., it does indicate some measure of the burden placed on the Board and their consumers by reason of the compensation paid to the companies for the goodwill of the undertakings. The extinguishment of the "acquisition debt" within the period of 80 years from 1923 is one of the principal items of the Board's expenditure.

There seems to be no doubt that the terms of the arbitration award were not unfavourable to the companies and indeed in the judgment of not a few they have been regarded as generous. Probably the companies themselves thought so. It is recorded that Sir Henry Knight, Chairman of the Southwark and Vauxhall Company, on hearing of the award to his Company declared that he would "go and take poison." His Counsel, Balfour Browne, with a truer sense of values, remarked "The only poison he will take is a bottle of champagne."

A substantial sum (£219,287) was paid to the Directors of the water companies as compensation for loss of office, this

being based on an average of 7.2 years' purchase of the average annual fees paid over five years plus 5 per cent. income tax.

If the Commissioners were generous in their awards to the companies it has to be conceded that they acted with exceptional decorum so far as their own advantage was concerned. Sir Edward Fry, the President, was entitled to receive £5,000, but subsequently wrote to the Chairman of the Board stating that he did not wish to retain for himself more than £1,500, the difference between his previous salary as a Lord Justice of Appeal and his pension. He therefore returned the balance of £3,500, less income tax, and a sum of £250 which he presented to the Institution of Mechanical Engineers for their courtesy. Sir Hugh Owen also reduced the fee sanctioned by the Local Government Board by £1,200, the amount of his pension and income tax.

Meanwhile, as the case for arbitration was proceeding, other matters of a more domestic character had to be settled. It will be appreciated that it became necessary for the Board to adopt a symbol of incorporation and a plain seal was temporarily used. On 16th October, 1903, however, the Board adopted a seal from a design by Mr. H. W. Lonsdale. This design shows a figure representing London, drawing water from a reservoir of masonry which is supplied by a stream issuing from a rock, symbolising the artificial distribution of water obtained from a pure source. In the background are St. Paul's and the Towers of Westminster, indicative of London generally. This seal remained in use until June, 1931, when it was replaced by the present one, incorporating the Board's Coat of Arms.

The provision of office accommodation too was urgent, for although the venue for meetings of the Board could to some extent be adjusted to the exceptional circumstances of the time, a nomadic existence for the office staff would hardly conduce to efficiency. One of the first things then that the Board had to do was to find an office, but here again the question arose as to what would eventually be the most suitable location and arrangement after the transfer had taken place and unification had been effected. It could not be immediately answered and so only temporary accommodation for the staff who had been actually engaged was sought in the first instance.

Suitable rooms for this purpose and for meetings of the Committees were found at Caxton Hall, formerly Westminster Town Hall.

With the advent of the transfer of the undertakings, however, more room became necessary, and after considering various premises the Board eventually took a lease of a block of new buildings on the west side of Savoy Court, Strand, in May, 1904, and the move took place in August of that year. The lease was for twenty-one years at a rent of £3,500 a year. With the centralisation of the Board's financial work involving the transfer of a large staff from the district to the central offices, further space had to be found, and at the end of the year 1905, rooms on the first and second floors of the East Block at Savoy Court were leased, at £400 per annum for those on the first floor and £600 per annum for those on the second floor.

These offices continued to be occupied by the Board until March, 1918, when, as a result of the Cabinet Committee on Accommodation acquiring Savoy Court for an extension of the Air Board offices, the Board moved to Armfield's Hotel, South Place, Finsbury. This building was destroyed by enemy action in 1940.

There are still on the Board's staff some who can look back on the early days at Savoy Court. Whether it is the name that lingers or whether it is the memory of frock coats and top hats which many of the staff used to wear, or whether it is the attraction of the Strand, are matters for speculation. Certain it is, however, that to some there has never been a period to compare with the "Savoy Court" days.

Financial Officer

In November, 1903, the Board decided to appoint an Accountant and in response to a public advertisement 94 applications for the position were received. Mr. Frederick E. Harris, Treasurer and Accountant of the County Borough of West Ham was appointed on 22nd January, 1904.

Mr. Harris was soon engaged on duties in connection with negotiations which terminated in agreements with the water companies that they should take Stock instead of cash, and also in connection with the financial arrangements relating to the transfer of the undertakings of the water companies.

SAVOY COURT, STRAND, ABOUT 1910

No. 20, NOTTINGHAM PLACE, W.1.
Home of the first laboratories

In recognition of the fact that the larger part of the work described was not that of an accountant only, the Board, in October, 1904 on the advice of the Finance Committee, altered Mr. Harris's designation to Comptroller to the Board, and increased his salary.

Mr. Harris, who died on 20th January, 1908, was succeeded by Mr. Arthur Newton, deputy comptroller at the time and the former accountant to the Southwark and Vauxhall Company. In his new appointment he was designated Accountant to the Board. It may here be remarked that the designation of Comptroller was revived in 1936 when the Chief Cashier of the Bank of England, at his own request, was relieved of the appointment of Treasurer of the Board. To comply with the provisions of the Metropolis Water Act, 1902, it was necessary to appoint someone else to the position and on 5th May, 1936, the Board conferred the appointment on Mr. A. V. Huson, the Accountant. Having regard to the responsibilities of the office, the Board at the same time altered Mr. Huson's designation to "Treasurer and Comptroller." The present holder of the position bears the same title.

Centralisation of Clerical Staff

Apart from the arbitration proceedings and the financial and other considerations arising therefrom the question of the management of the several undertakings after the appointed day engaged the attention of the Board.

In pursuing a policy of centralisation it was necessary to proceed carefully so as to avoid inconvenience to the public by a general dislocation of business. Each company's chief office was therefore treated as a district office of the Board under the supervision of the Clerk of the Board so far as matters of administration and general business were concerned, and of the Comptroller as far as related to financial matters. The Secretaries of the East London, West Middlesex and Grand Junction Companies were superannuated immediately before the appointed day and were succeeded by their chief assistants who were appointed to be district secretaries at their then existing salaries.

By February, 1905, the transfer of general administration as

distinct from purely local business had advanced considerably and the Clerk of the Board was able to make arrangements for rendering himself independent of the assistance of the district secretaries as from 31st March, 1905. The Comptroller also, with three exceptions, no longer required the services of those officers, the financial work to be carried on at the district offices after that date being such as could be entrusted to subordinate members of the district staff under his supervision. The offices of five of the district secretaries (New River, Chelsea, Kent, Southwark and Vauxhall, and Lambeth) were therefore abolished as from 31st March, action in the cases of the East London, Grand Junction and West Middlesex offices being postponed.

Concurrently with this the centralisation of the revenue section of the Comptroller's department began with the creation of the position of chief revenue officer in 1905.

By the end of February, 1906, the district secretarial organisation had disappeared, having been consolidated under the Clerk of the Board at the central offices. Similarly in the Comptroller's department, after an interim system of financial control under district revenue officers who succeeded the district secretaries, much of the work was concentrated at Savoy Court. In 1911, when various of the district revenue officers' areas had been amalgamated and their numbers reduced to three, the final stage of the centralisation of this part of the work was reached. The position of revenue officer was created, and those of chief and district revenue officer were abolished.

A detailed description of the administrative and financial arrangements of those days would form an interesting chapter of its own. Here it is possible to remark briefly on one or two aspects only, these being chosen because of their preponderant influence and of the fact that, directly or indirectly, they were of concern to the public.

Collection of Water Rates and Meter Rates

The collection of water rates for domestic and meter supplies was at the appointed days left to be undertaken by the local offices attached to the district offices, and other financial

operations most readily lending themselves to centralisation were transferred to the Board's central office.

The domestic water rate constitutes the most important source of the Board's revenue and amounted to about £1,980,000 per annum in 1904–05, the number of these supplies being over 964,000. The methods of administering this section of work varied under the companies' management to such an extent that the need for the closest possible scrutiny of the thousands of financial transactions involved became a matter of great importance. In order to provide the Comptroller with assistance in this branch of the work the offices of inspector and assistant inspector of collectors' accounts were created.

At the appointed days there were 147 collectors and assistant collectors, many of whom were paid by commission in lieu of salary, a practice which, in the opinion of the Board, was undesirable, and whenever a suitable opportunity occurred payment by commission was abolished and an inclusive salary substituted.

The collection of meter charges produced an income of about £668,000 in 1904-05 and involved over 27,000 separate supplies. Again the practice relating to the collection of this form of revenue varied considerably with the companies. In some cases a special staff was kept at the chief office for the purpose while in others the collection was conducted very largely by the collectors, a proportion only of the rentals for large supplies to public authorities, etc. being collected from the companies' chief offices.

The Board adopted the principle that the collection of all meter charges ought to be managed entirely from the Board's central office, but it was impracticable to effect this change immediately.

In May, 1908, the Board instructed the well-known firm of chartered accountants, Messrs. Deloitte, Plender, Griffiths & Company to report "on the general principles governing the system of keeping the Board's accounts, and whether the accounts and balance sheets in their opinion represented the true financial position of the Board's undertaking as between capital and revenue."

With regard to the first question put to them, the firm reported that in view of the magnitude of the work of con-

centrating the varied systems of accounting previously in operation, the arrangement and condition of the records reflected great credit upon those responsible for their design and administration. In reply to the second question they stated that they had been unable to discover any revenue item charged to capital, and that the principles recognised for apportioning current expenditure between capital and revenue were theoretically correct and in accordance with commercial usage.

Certain recommendations of the consultants were either anticipated or were subsequently given effect to, and the fact was thus established by independent testimony that the accounts of the Board correctly represented the true financial position of the undertaking in every respect.

Some reorganising changes were made, to take effect immediately after the close of the 1908-09 financial year. The Southern and Kent districts were amalgamated for revenue purposes and housed at the Southwark Bridge Road offices. The collection of meter accounts, previously carried out at the respective district offices, was centralised at Savoy Court; a cash section was formed; and further progress was made with the revision of collecting districts, with the object of increasing the system of indoor office collection where desirable, thus reducing the number of rate collectors and effecting both immediate and future economy.

A less familiar feature but one which is also of much importance to the Board concerns the assessment of charges for water supply.

Under resolutions passed by the Board in February, 1905, the departmental work in connection with the assessment of charges based on rateable or annual value was conducted by the Comptroller's department, while work connected with the assessment of charges for special supplies such as those for road watering, building purposes, automatic sprinklers and flushes, gardens, hydrants, motor vehicles and supplies to local authorities, etc., was undertaken by the Clerk's department. By December, 1910, however, in the light of six years' experience this arrangement proved unsatisfactory and the Board therefore decided that as from the 1st April, 1911, the whole of

the departmental work involved in the assessment of charges both domestic and non-domestic should be consolidated and conducted in the Clerk's department under the direction of an officer designated Supervisor.

In May, 1919, the Supervisor's section was severed from the department of the Clerk of the Board and a new department under that name was formed, with Mr. F. W. Drake as its head. Mr. Drake had occupied a somewhat similar position under the New River Company since 1895 and subsequently under the Clerk of the Board. On his retirement in 1927 after nearly 50 years' service with the Company and the Board, his department was absorbed in the Accountant's department in which a separate section was formed to deal with the assessment of water charges. As a result of certain measures of re-organisation in 1932, the section was placed under the Chief Engineer but in 1939 returned to the department of the Treasurer and Comptroller.

Appointment of Auditor

Under the Act of 1902, the Board's accounts are subject to audit in the same way as those of County Councils and in July, 1904, the Local Government Board issued an order assigning to Mr. Arthur Carson Roberts, District Auditor, the audit of the accounts of the Metropolitan Water Board for each of the financial years ending 31st March, 1904, and 31st March, 1905. Mr. Carson Roberts continued to audit the Board's accounts for many years.

Legal Work

The legal business of the water companies was conducted by various firms of solicitors and on the transfer of the undertakings those firms continued to act for the Board in the matters upon which they happened to be engaged. On other matters the Board consulted Messrs. Linklater, the solicitors who acted for them in the arbitration proceedings but the Clerk of the Board being himself a solicitor, a large part of the legal work was subsequently conducted by him. A legal branch of his department was created and Mr. Walter Moon was appointed Law Clerk responsible to the Clerk of the Board in November, 1904. In March, 1906, the legal branch was estab-

lished as a separate department under Mr. Moon as Solicitor to the Board.

Contracts

An early opportunity was taken of acting on the principle that goods to be supplied should be made the subject of competitive tender, the first important matter to which the principle was applied relating to printing and stationery, tenders for which were invited in October, 1903.

The question of the rates of wages and hours of labour applied by the Board's contractors also received attention, and pending the settlement of general clauses the following clause was adopted in November, 1903, in the case of the contract for printing and stationery:

> "The contractors hereby declare that they will pay such rates of wages and observe such hours of labour as are generally accepted as fair in their trade."

The subject received further consideration at a later date, with the result that on the 13th May, 1904, the Board directed that the following clauses should be inserted in contracts for the supply of goods or services:

> "The contractor shall not without the written permission of the Board assign or sublet this contract or any part thereof, but this prohibition shall not refer to such subletting as may be customary in the trade concerned.
>
> "The contractor shall pay to all workmen employed by him in or about the execution of this contract or any part thereof, such rates of wages and observe such hours of labour as in the district in which the work is to be executed are generally obtained and recognised by associations of employers and trade unions, and will throughout the execution of the contract prominently exhibit a copy of this clause in the workshops and where work for the Board is carried on."

Organisation of the Chief Engineer's Department

The question of appointing a Chief Engineer came before the Board in May, 1904, when they adopted the principle that the Chief Engineer should be appointed for the whole of the works transferred to their control and that he should be required to give his whole time to the duties of the office and should not be allowed to take private practice.

As a result of advertisements thirty-seven candidates applied for the appointment including several officers of the companies. Out of these, the names of three candidates were submitted to the Board, Mr. W. B. Bryan, Chief Engineer of the East London Waterworks Company, Mr. Ernest Collins, Distribution Engineer of the New River Company and Mr. H. F. Rutter, Engineer of the West Middlesex Waterworks Company. On 24th June, 1904, the Board appointed Mr. Bryan to the position at a salary of £3,750. He was allowed to retain his post of consulting water engineer to the City of Nottingham until certain works were completed.

Although the Metropolis Water Act received the Royal Assent in December, 1902, the undertakings of the metropolitan water companies did not become vested in the Board until June and July, 1904. It was not until March, 1905, therefore, that the Board saw their way to reorganise the engineering structure that had grown up with the companies.

When the Board took over, the companies' areas and the water undertakings of the Enfield and Tottenham Urban District Councils formed distinct units with the minimum of intercommunication between them.

The companies' areas were in the first instance merely renamed districts of the Board. They varied considerably in importance, as will be seen from the number of supplies shown below:

Chelsea	39,871
East London	231,154
Grand Junction	78,374
Kent	111,669
Lambeth	135,274
New River (including Tottenham and Enfield)	203,824
Southwark and Vauxhall	130,221
West Middlesex	91,467
Total ...	1,021,854

The total population of "Water London" at the time was nearly 6¾ millions.

At their meeting on 31st March, 1905, the Board adopted the first plan for reorganising the department. This reduced the number of districts in the Board's area to five, namely:

Name	*Former Areas included*	*No. of Supplies*
New River	New River (including Tottenham and Enfield)	203,824
Eastern	East London	231,154
Western	Chelsea, Grand Junction and West Middlesex	209,712
Southern	Southwark & Vauxhall and Lambeth	265,495
Kent	Kent	111,669
		1,021,854

The division resulted in each district (except the Kent) having over 200,000 supplies. The Kent district, however, was the largest in area (178 square miles) and included one quarter of the whole of the administrative County of London. Its population, moreover, was rapidly increasing and its supply, then entirely from wells, was different from that of any other part of the Board's area.

With the adoption of this plan the Board approved the appointments of the following principal officers of the department:

Deputy Chief Engineer.
Chief Assistant Engineer.
District Engineers.
Assistant District Engineers.

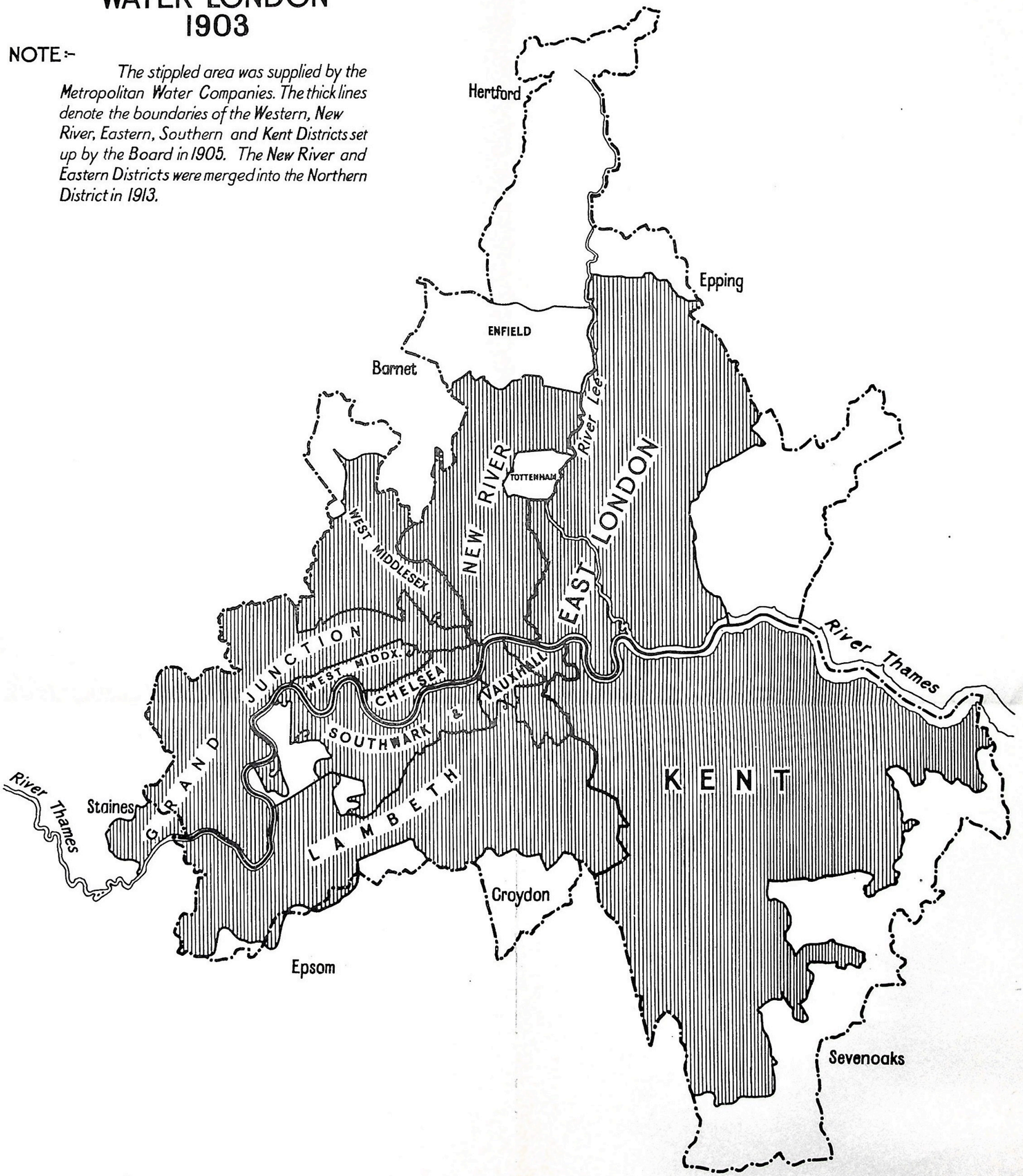
The deputy chief engineer was to act in the absence of the Chief Engineer and assist him in the supervision of the works, whilst the chief assistant was to relieve the Chief Engineer of the bulk of the detail work and see that the business was so arranged as to enable him to give adequate attention to the greater questions which would continually come before him.

The district engineers, officers with a complete knowledge of the working of every detail in the area under their control, were to relieve the Chief Engineer of all routine work in the

THE PARLIAMENTARY BOUNDARY OF "WATER LONDON" 1903

NOTE:-

The stippled area was supplied by the Metropolitan Water Companies. The thick lines denote the boundaries of the Western, New River, Eastern, Southern and Kent Districts set up by the Board in 1905. The New River and Eastern Districts were merged into the Northern District in 1913.



could thus be carried out more effectively. Both districts were largely dependent on the River Lee and wells situated within its watershed. This new district, called the Northern district, was divided into two divisions, the north and south, each supervised by a senior engineering assistant. The south division comprised the Metropolitan Boroughs within the areas of the former Eastern and New River districts, with the addition of the County Borough of West Ham and the Borough of East Ham. The north division consisted of the remainder of the area of the two former districts. The officer in charge of the south division was to be located at the New River central office, and the officer in charge of the north division at Lee Bridge. The whole of the work connected with the pumping machinery, buildings, maintenance of the rivers, aqueducts and storage reservoirs was placed under the charge of an officer on the district engineer's staff called the resident engineer whose headquarters were at Lee Bridge.

Director of Water Examination

The Board decided to appoint a permanent officer to control the examination of the water and on 21st July, 1905, after public advertisement, appointed Dr. Alexander Cruickshank Houston (later Sir Alexander Houston) out of 38 applicants to the position of Director of Water Examination. The offices of Sir William Crookes and Sir James Dewar, whose services to the companies in regard to water examination had been continued by the Board, were abolished as from 31st October, 1905, and the conduct of the water examination passed into the hands of Dr. Houston on that date.

Lands

An important part of the Board's administration transferred from the several companies was in connection with lands and properties, including the purchase, alienation and management generally, such as easements, dedications, leases, licences, rights of way, sublettings, tenancies and wayleaves. The properties of the Board are considerable and of a most varied description, including grazing and agricultural land, valuable building sites, riverside land and wharfage, and other property in and around London. They extend into the

neighbouring counties of Buckinghamshire, Essex, Hertfordshire, Kent, Middlesex and Surrey. The gross annual income derived therefrom in 1905/06 was over £12,000. Upon taking over these properties at the appointed day, the Board continued for the time being the arrangements made by some of the companies with certain firms of estate agents and valuers for the management of the properties belonging to the companies. On 10th November, 1905, however, it was decided to appoint a permanent officer as estates clerk in the department of the Clerk of the Board, to undertake all matters relating to the management of the Board's estates, to compile and keep registers and map books, and to render assistance in connection with the assessment of the Board's property to local rates and the assessment of other property for water rates. The title of estates clerk was changed to Surveyor in 1907.

The total area of the Board's lands as at the 28th February, 1910, was:

	Acres
Area occupied by works	3,709
Area let	1,312
Area in hand	179
	5,200

The Surveyor's section was constituted a separate department on 22nd February, 1924.

CHAPTER V

The Years of Deficiency

1908—1922

PROMINENT among the important questions which soon occupied the attention of the Board was the discharge of the obligation placed upon them by the Metropolis Water Act, 1902, to promote within three years from the appointed day a Bill providing for uniform scales of charges applicable throughout the limits of supply.

This matter was one of some complexity, difficulties arising mainly from the varying scales of charges of the several companies for domestic supplies and the existence of a variety of extra charges, the varying statutory scales—and practices where there were no such scales—for the supply of water for trade purposes, public purposes and combined domestic and non-domestic use and the difference in the basis of domestic charge within and without the Metropolis. Many of the charges had been in force for 50 years.

The authorised charges for supplies for domestic purposes ranged from 7½ per cent. in the case of houses of low rateable value in the Lambeth district to 3 per cent. in the case of houses exceeding £200 rateable value in the Chelsea, Grand Junction, New River and West Middlesex districts.

There was strong opposition to the Bill as promoted from the many interests which would necessarily be adversely affected by any scheme for uniformity. There were petitions from 4 County Councils, 20 Corporations and Metropolitan Boroughs and 13 Urban District Councils. Petitions from sundry other bodies totalled 14.

On the main points at issue the Joint Select Committee to whom the Bill was referred, ruled:

1. That the basis of assessment for domestic charge both within and without the Metropolis should be the rateable value.
2. That the charge for domestic purposes should be at a uniform

rate not exceeding 5 per cent. on the rateable value—to include the charges for "extras."

3. That any rebate allowed in the case of special properties should be uniform and applicable to the whole area.

4. That traders should not be bound to have a domestic supply in order to be entitled to a supply by measure for trade purposes.

5. That the charges for trade supplies should not be governed by a maximum charge but should be regulated by a scale to be embodied in the Act.

Parliament endorsed the findings of the Joint Select Committee. The Bill received the Royal Assent on 28th August, 1907, as the Metropolitan Water Board (Charges) Act, 1907, which came into operation on 1st April, 1908.

The charges scheme as promoted in the Bill had been designed to produce equilibrium between the income inherited from the companies and that to be derived from the new uniform charges. It showed in fact an estimated increase of only £1,700 per annum. During the passage of the Bill, however, changes were imposed which converted this estimated increase into an estimated decrease of £27,000, representing a loss to the Board of nearly £29,000 per annum.

The years 1908-9 to 1921-22 were years of deficiency and the Board were being constantly called upon to deal with complaints regarding the method provided in the Charges Act for the liquidation of deficiencies in the Water Fund. Conferences of local authorities were held, resolutions passed, deputations waited on the Board and legislative reform was urged. The administration of the Board became suspect and was the subject of much unfriendly criticism in the Press, particularly in the City of London.

The financial results from the year 1904-5 to 1922-23, the year when the Board's Charges Act of 1921 first came into operation, were as follows:

Year	*Surplus*	*Deficiency in revenue account met by precepts on the contributory authorities*	*Contribution to the redemption funds set up in respect of the debt incurred in extending the undertaking*
	£	£	£
1904–5 }	2,288	—	{ 3,800
1905–6 }			{ 8,577
1906–7 ...	26,504	—	16,577

Year	*Surplus*	*Deficiency in revenue account met by precepts on the contributory authorities*	*Contribution to the redemption funds set up in respect of the debt incurred in extending the undertaking*
	£	£	£
1907–8 ...	933	—	21,820
1908–9 ...	—	25,279	28,774
1909–10 ...	—	46,076	53,805
1910–11 ...	—	64,480	74,422
1911–12 ...	—	73,737	82,752
1912–13 ...	—	63,647	82,791
1913–14 ...	—	15,385	82,073
1914–15 ...	—	94,873	89,689
1915–16 ...	—	224,153	95,769
1916–17 ...	—	242,264	109,902
1917–18 ...	—	284,923	98,864
1918–19 ...	—	530,785	100,207
1919–20 ...	—	984,867	88,327
1920–21 ...	—	1,812,252	108,571
1921–22 ...	—	1,925,338	171,088
1922–23 ...	560,900	—	168,092

It will be observed that as from 1908-9, the year in which the charges in the new Act became operative, there was a progressive deterioration in the financial position and that until the first world war this deterioration coincided more or less with the appropriations to the extension debt redemption funds.

The Board soon appreciated the latent seriousness in the situation and in January, 1910 instructed the Finance Committee to prepare and submit to the Board a full report on the financial position, comparing the position of the undertaking at that time with that of the late metropolitan water companies, and giving such information as would enable the Board to judge whether an equilibrium as between the receipts and expenditure was likely to be attained in the near future.

The main substance of the Committee's report to the Board was as follows:

The effect of the Metropolis Water Act, 1902, had been to convert the capital of the undertakings of about £22,900,000 (£22 13*s.* 7*d.* per service) into a net capital debt of the Board of nearly £46,000,000 (£46 9*s.* 9*d.* per service). In addition

down to 31st March, 1911, the Board had had to face expenditure on the extension of the undertaking of approximately £2,600,000 (£27 2*s.* 2*d.* per service laid since the transfer), whilst capital outlay of about £36,000 had been defrayed out of direct contributions from revenue account.

The transfer of the capital of the companies had the effect of converting dividends susceptible of adjustment to meet the exigencies and vagaries of particular years into fixed interest payable every year whatever the financial result.

So far as income from water charges was concerned, whilst there had been an increase year by year since the transfer this increase had been at a diminishing rate. During the last five years of the companies the average increase per annum had been £66,053. This compared with £28,438 for the years 1906–7 to 1910–11. In the three years to 31st March, 1911, when the uniform scale of charges was in operation, the average annual increase was only £12,834.

Since the transfer there had been a diminution in the rate of increase of consumers due to a fall in the rate of growth of population. The error in the forecast of population by the Balfour Commission was becoming evident. (See p. 102).

The tide of prosperity in the building trade, of which the companies had had the advantage since 1893 and which had been in full flood from 1899 to 1903, had ebbed and by 1911 had returned to the low water mark of 1893. Expectation of continued growth had been frustrated. There seemed little doubt that the companies had been able to sell their undertakings at the top of the market.

The Finance (1909–10) Act had occasioned large reductions in the value of licensed premises and on this account there was an approximate fall in annual income of £17,000.

Recent quinquennial re-valuations of the Metropolis had shown a serious drop in the rate of increase over the previous quinquennia, the figures of increase for the last three re-valuations being:

Year	*Increase per cent.*
1901	10.76
1906	9.31
1911	3.00

The last re-valuation had also shown for the first time an actual decrease of value as compared with the preceding year occasioning a further annual loss of £8,000.

The revision in Parliament of the charging scheme in the 1907 Bill had cost the Board £29,000 per annum.

Since the passing of the Charges Act no fewer than 22 wells had been sunk in the City of London so that properties with a total rateable value of nearly £500,000 did not contribute to the Board's revenue although enjoying the valuable advantage of fire protection without which they would in many cases have been uninsurable as a fire risk. The annual loss under this head was estimated at £24,500.

All these factors were beyond the Board's control.

On the expenditure side it was noted that rates and taxes in 1911–12 were £80,000 above the figure for 1903–4; that interest, dividends and annuities which in the last year of the companies amounted to £1,454,000 would amount in 1911–12 to £1,500,000; by the end of 1910–11 contributions to the redemption funds set up in respect of debt incurred on works of extension since 1904 would total £208,000; and there was the ultimate liability in respect of the acquisition debt, whereas in their last year the companies contributed only £40,652 to the Chamberlain of London's Sinking Fund.

This Fund had come into existence as the result of a Clause first introduced in the East London Company's Act of 1886, and subsequently applied to all the water companies, under which the Chamberlain of the City of London was appointed as trustee to hold all money or other property applicable as a Sinking Fund towards the purchase of the companies' undertakings.

Had the concept of purchase for public ownership been finally rejected by Parliament and had the companies been left undisturbed, it was conceivable that the burden of contributing to the Chamberlain of London's Sinking Fund as a temporary expedient for the purpose of early purchase of the undertakings would have been removed and the fund itself liquidated.

Payments to the Thames Conservancy had increased from

£28,148 in 1903–4 to £33,402 in 1911 and would increase in 1912 to £40,000.

Payments in respect of abolition of office, which was of course an expiring commitment, amounted to £41,460 per annum.

In the last five years of the companies the cost of superannuation averaged £20,215 per annum. In the five years to 31st March, 1911, the average cost to the Board of the superannuation of transferred officers was £31,793 whilst the cost to the Board of their own superannuation scheme in 1911 was £11,000.

The wages paid by the Board were higher than were those paid by the companies and conditions of labour were improved.

Much more was being spent on purification of water than in the days of the companies.

Composition for stamp duty was not a charge on the companies whereas for the current year payments by the Board amounted to £18,170. On a moderate estimate management of stock issues was costing the Board annually £7,000 more than the companies.

Much of this foregoing expenditure was beyond the control of the Board and the remainder was incurred in the interests of the undertaking.

The Board had achieved a saving in the cost of the administrative salaried staff. From 31st May, 1904 (immediately prior to the appointed day) to 1st April, 1911 it was computed in terms of the number of supplies that the volume of the Board's business had increased 12.41 per cent. whereas the expenditure on salaries and management of (B) Stock had decreased by 10.44 per cent.

The Committee stated that they had given consideration to the question of the levying of precepts on the contributory authorities to meet the deficiency in the Water Fund of £209,572 which had accumulated over the four years to 31st March, 1912. Section 15 of the 1902 Act provided that the deficiency should be apportioned "amongst the City of London and the metropolitan boroughs in the County of London and the municipal boroughs and urban districts outside London, the Councils of which are for the time being entitled to be represented on the Water Board in proportion to the rateable

value appearing in the valuation lists on the preceding sixth day of April of the hereditaments at that date supplied with water . . . in the City and each such borough and district."

In the view of the Committee this machinery was "so cumbersome and involved that any attempt to put it into operation must of necessity lead to expensive and protracted litigation." They had formed the strong opinion that every effort should be made to avoid levying a deficiency rate and that Parliament should be asked to review the situation so that new provisions on a more simple and equitable basis might be enacted. In conclusion they felt that any charge of extravagant administration could not be substantiated.

As a result of their consideration of this report the Board resolved that it was expedient that appropriate legislation should be promoted at the earliest opportunity. They authorised the Finance and Appeal & Assessment Committees to place this view before the Local Government Board who concurred therein. A Special Committee was then appointed to consider what legislative amendments ought to be proposed.

The Special Committee reported in July, 1912, that they were impressed by the advantage of retaining unimpaired the unlimited rating powers conferred by section 15 of the 1902 Act as being a factor of first rate importance in maintaining the credit of the Water Stock. They were "animated by the desire to avoid interference with the principle of apportionment adopted by Parliament whilst at the same time making such alterations as will remove the difficulties now encountered in putting it into practice." They believed that these objects could be attained if the apportionment took place according to the revenue derived from each district instead of the rateable value of the hereditaments supplied in each district as required in the Act.

A draft Bill was accordingly prepared to amend appropriately the precepting powers in the 1902 Act to provide for the liquidation of the accumulated deficiency over a term of years and to provide that future deficiencies might be accumulated where they did not exceed specified amounts.

This Bill, however, was not proceeded with and the only

course then open was to proceed to issue precepts to cover the accumulated deficiency.

This intention having been communicated to the contributory authorities, a conference of such authorities was held at the instance of the Metropolitan Boroughs Standing Joint Committee in the Guildhall on 17th March, 1913.

At this conference there was little expression of any desire to embarrass the Board or to avoid payment of the deficiency, it being recognised that the money must sooner or later come out of the public purse and that litigation would only increase the amount to be paid. Resolutions were passed reinforced by a deputation to the Board, urging that legislation should be promoted for the removal of doubt as to the legality of issuing precepts in respect of a deficiency accumulated over several years and asking that the actual issue of the precepts should be postponed pending the result of such action.

The Board accordingly petitioned Parliament for permission to insert an appropriate clause in the Metropolitan Water Board Bill, 1913, then before the House, and the issue of the precepts was delayed.

In May, 1913, the London County Council, whose Parliamentary Committee had reported fully on the matter, addressed a communication to the Board urging that power should be sought to levy precepts on estimated deficiencies and not as provided in the Act on ascertained deficiencies. The delay occasioned by the latter method, which was likely to be considerable, would mean that in many cases the ratepayer charged with a rate arising on a precept was not the ratepayer in occupation when the deficiency was incurred. The change suggested by the Council would mean that current obligations would be met by current ratepayers. Moreover the holding over of the deficiency until ascertained and certified would mean that there would be a permanent deficit in the Water Fund to be met presumably by temporary loans the interest on which would increase the annual deficiency.

In June, 1913, a conference of contributory authorities called by one of the Metropolitan Boroughs passed resolutions objecting in principle to the method of precept and urging that the Metropolis Water Act, 1902 should be amended so that any surplus in the Water Fund should not be transferred to the

redemption fund if it were estimated that a deficiency might arise in any future year; and that deficiencies should not be the subject of precept but should be collected direct by the Board.

The Board were unable to accept the recommendations of this conference but thought that there was much to be said in favour of the principle formulated by the London County Council, namely that if when approving the annual estimates of income and expenditure on revenue account for any year it appeared to the Board that there would be a deficiency for that year steps should be taken to provide funds to meet the deficiency in that year. The Board were not prepared to take action in the matter at that time. They reserved the right, however, to give further consideration to the principle involved, and an appropriate amending section appeared in due course in the Charges Act of 1921.

The Metropolitan Water Board Act, 1913, received the Royal Assent on 15th August, 1913. The doubt as to the legality of precepting for the accumulated deficiency of £209,572 was removed by section 81 of this Act and the necessary precepts were issued. Precepts in respect of deficiencies arising in subsequent years were levied following certification by the District Auditor.

In 1914, the view was expressed that as there was likely to be a yearly deficiency in the Water Fund the Board should seek power to apportion the deficiency amongst all the local authorities in their area irrespective of representation on the Board.

In the light of information submitted by the Finance Committee the Board came to the conclusion, however, that a sufficient case for application to Parliament had not been made out. An intimation to this effect with a copy of the report of the Finance Committee was sent to the local authority who had raised the matter and to the other contributory authorities.

The London County Council urged that the standard of valuation in London was higher than in the outside districts and pressed the Board to take steps to ensure that the deficiency in the Water Fund should be borne equitably by all districts supplied.

In May, 1918, a conference was held at Caxton Hall,

Westminster, at which 52 of the contributory authorities were represented. The original purpose of this conference was the promotion of a petition to the Local Government Board by all the contributory authorities asking for an enquiry to be made into the affairs of the Water Board.

The conference appointed a Committee of sixteen which held three meetings, twelve members attending the first, six the second and three the third. The report of this Committee consisted of an ill-digested mass of figures and statements extracted from the Board's accounts and other published documents neither leading up to nor justifying certain drastic recommendations which impugned the Board's management as extravagant and out-of-date, and urged the appointment of a general manager, the collection of the Board's charges with local rates and the advance issue of precepts.

A report of the Finance Committee in criticism of these recommendations was adequate and convincing and by resolution of the Board copies were forwarded to the contributory authorities.

In December, 1918, the Board decided not to seek the temporary relief from their embarrassments which might have been made available to them by an application to the Local Government Board for an order under the Statutory Undertakings (Temporary Increase of Charges) Act, 1918.

On 23rd May, 1919, the Finance Committee recommended to the Board that an enquiry should be held into the provisions and effect of the Metropolis Water Act, 1902.

The Metropolitan Borough of Hammersmith had asked the Local Government Board to appoint a Special Commission or to make a Departmental Inquiry into the finances and methods of working of the Water Board. Many constituent authorities had supported this request and the London County Council were again urging the Board to legislate for the establishment of a more equitable method of dealing with deficiencies.

The Finance Committee pointed out that the approximate deficiency for the year ended 31st March, 1919, was £511,000 and that the estimated deficiency for the year to 31st March, 1920, was £681,000. Additional expenditure would arise from a recent Trade Union decision under which hours of labour

were reduced, whilst from four years hence annual contributions amounting to £144,000 would be payable to the Acquisition Debt Redemption Fund. In these circumstances the Board must contemplate a deficiency in the neighbourhood of £900,000 per annum. As will be seen by reference to the table on pages 49-50 these figures were greatly exceeded.

The Committee concluded that the question of the policy to be adopted in dealing with a deficiency of this order would be one of grave importance. Whether the deficiency should be charged to the rates or wholly or partially met by an increase in the water charges was a matter upon which members of the Board were known to be more or less equally divided in opinion and the Committee suggested that it might be well to refer the question to an independent and impartial tribunal constituted by H.M. Government, leaving it to the Board subsequently to promote legislation to give effect to these findings if and when approved by the Government.

In the consideration of this matter it had seemed to the Committee important to bear in mind that whilst the Board was a self-contained and independent entity, it nevertheless existed for the purpose of carrying out the provisions of the Metropolis Water Act, 1902, a measure promoted by the Government itself, and it was possible that after sixteen years' experience of its operations an opportunity ought to be taken for an enquiry by the Government as to whether any amendments in the law were required. The Board had no reason to avoid such an enquiry which, doubtless, would have the salutary effect of removing any misapprehension in the public mind and of relieving the Board of much of the adverse criticism which had been levelled against it.

The Board accordingly resolved:

> "That a communication be addressed to the Local Government Board stating that in view of the extent of the deficiency in the Water Fund which will have to be provided for at a comparatively early date, and of the large items of annual expenditure which are beyond the Board's control, the Water Board would welcome an enquiry by a competent and impartial tribunal into the provisions and effect of the Metropolis Water Act, 1902."

The Ministry of Health (formerly the Local Government Board) subsequently appointed a Departmental Committee

to make such an inquiry. The constitution of the Committee was as follows:

Sir Horace Monro, K.C.B. (late Permanent Secretary of the Local Government Board) *Chairman.*

Mr. F. J. Willis, C.B. (Senior Assistant Secretary, Ministry of Health).

Mr. E. A. Lees, O.B.E. (Secretary & General Manager, Birmingham Corporation Water Works).

Major General Sir Henry Thornton, K.B.E. (General Manager, Great Eastern Railway).

Mr. R. C. Norman (late Chairman of the London County Council).

Sir Gilbert Garnsey, K.B.E. (partner in Messrs. Price Waterhouse & Co., Chartered Accountants, and late Comptroller of Accounts to the Ministry of Munitions).

Mr. G. H. Stuart Bunning, O.B.E. (Chairman, Trades Union Congress).

The Committee of Inquiry, as will be seen, was to vindicate the Board's methods of management; and the Charges Act of 1921, largely based upon the proposals of the Committee, was to enable the Board greatly to improve their financial position and so to carry out effectively their statutory obligations.

CHAPTER VI

The Monro Committee

1919—1920

THE Departmental (Monro) Committee held twenty meetings between November, 1919 and April, 1920, and considered in detail written and oral evidence on behalf of the Board and a considerable number of interested bodies and councils. Their report was published in June, 1920. It substantially vindicated the Board's management and methods of control. The Committee stated:

> "Before the inquiry took place there had been current a certain amount of vague suggestion of mismanagement on the part of the Board. We have given the fullest opportunity to the witnesses who have appeared before us to criticise the administration of the Board and we are happy to be able to state that no serious charges of mismanagement have been brought. In fact the impression which we have derived from all the evidence is that this great undertaking has been well conducted. We will refer presently to certain matters of organisation to which we think attention should be drawn, but it is due to the Members of the Water Board (and particularly to its two Chairmen, Sir Melvill Beachcroft who was Chairman from its inauguration until 1908, and Mr. E. B. Barnard who has held the office since that date) and to the very able body of officials who have worked under them, to place on record the great obligation which the Board has conferred on the inhabitants of the Metropolitan area."
>
> "Throughout the period during which the Water Board has been in existence, its wide and populous area has been supplied with a safe and constant supply of water. Mr. Carson Roberts, the Auditor of the accounts of the Board, has given a very high testimonial to the excellence of the arrangements which have been made for securing the accurate and complete collection of its revenue, for managing its finances and presenting its accounts in a clear and intelligible form. So far as our investigations have gone, we consider that his remarks are well merited."

The following is a summary of the more important matters which were considered and of the Committee's findings thereon.

Annual cost of the undertaking in the hands of the Water Board

The Committee observed that while it was established that the undertaking in the hands of the Water Board had been brought to, and maintained in, a high standard of excellence, it was nevertheless a fact that the transfer of the duty of supplying the Metropolitan area with water from the eight companies to a single public body had not led to economy. It might have been expected that the amalgamation of eight distinct and separately controlled undertakings into one single body would result in considerable savings, and evidence was given before the Llandaff Commission with the object of showing that such savings would result. At first sight, therefore, it appeared somewhat surprising that not only had there not been any saving in total cost but the actual expenditures of the Board had been in excess of the total of the eight undertakings taken over and that the cost of the water supplied, whether measured per service or per 1,000 gallons, had risen.

The representatives of the Board pointed out in evidence before the Committee that they never held out any hope of savings such as those indicated by the witnesses before the Llandaff Commission, and that an increase of expenditure in certain directions was the necessary result of the transference of the management of the undertakings from private to municipal control.

Constitution of the Water Board

On the subject of the Board's constitution, and particularly the number of members appointed, the Committee received a variety of evidence. One witness suggested that in place of "a large unwieldy body of men" the constitution of the Board should be altered so as to require the Board to appoint four or five commissioners who would operate the affairs of the Board very much in the same way as a board of directors would carry on the affairs of a large commercial undertaking. The Committee were unable, however, to advise that this proposal be adopted as "it would be contrary to the distinct policy of the Act of 1902 to require the representative body established under that Act to delegate their responsibilities to another body of the kind suggested."

Sir Melvill Beachcroft, formerly Chairman of the Board, and at the time of the inquiry a member of the London County Council, considered that 66 members was too large a number. His impression was that the size of the body had led to less constant attendance of the members than would be the case with a smaller body, and that the fluctuations in attendance resulted in uncertainty in the decisions of the Board. Mr. E. B. Barnard, the then Chairman of the Water Board, on the other hand, did not advocate any reduction in the number of its members.

Sir Harry Haward, representing the London County Council, expressed his personal view that the Board was "much too large." Mr. John Hunt, the Town Clerk of the City of Westminster, by contrast, did not think sixty-six too large a number.

One witness thought it disadvantageous that the Water Board should consist of members over whom the ratepayers had no direct control, and wished it to be a body directly elected by the ratepayers. The Committee were unable to accept this suggestion.

The Committee's conclusion was:

> "It is outside the province of this Committee to discuss the rival advantages of municipal and commercial management of such an undertaking as that of the Water Board. That question was settled by Parliament in 1902 when it set up the new representative body to take the place of the Water Companies, but accepting the principle of municipal management we are disposed to think that a body of 66 is too large and we feel that a considerable reduction in the number of its members would add to the efficiency of the body."

Administrative organisation

The Committee were not entirely satisfied that the Board had done all that was required in order to derive full advantage from the unification effected by the Act of 1902. Whilst recognising that it was no doubt somewhat difficult to break at once with the past and that there were many other problems which claimed prior attention, they stated that "it is not clear why this movement towards the unification and concentration of the undertaking has not been more rapid." They added, however, that the Chief Engineer was at that time engaged upon the problem.

The Committee devoted a good deal of attention to the co-ordination of the Board's work and recommended that there should be some individual (a General Manager) "charged with the duty of looking at the undertaking from a wider standpoint than that of any one committee or of any one department, of co-ordinating its lines of policy, of securing that no matter of importance is omitted from consideration, and of scanning the future and anticipating its difficulties and its problems. . . ."

The income and expenditure of the Board

After examining the main heads of income and expenditure for a number of years, the Committee came to the conclusion that the factors causing the great excess of expenditure over income during recent years were largely outside the control of the Board and that under the prevailing conditions there was no immediate probability of a reduction in the expenses.

Beyond the broad question as to whether the Water Board had embarked on an unnecessarily extravagant programme of works for the storage and filtration of water, referred to later, the Committee said "We received very little evidence alleging extravagance on the part of the Board."

Proposals for meeting the deficiency

The Committee discussed proposals for meeting the deficiency in the Water Fund. They were opposed to the suggestion that there should be a public water rate as part of the ordinary revenue of the Board, and expressed the view that the right course was so to fix the charges to consumers that the revenue estimated to be derived therefrom would be sufficient to meet expenditure.

The ultimate right to have recourse to the rates to meet deficits ought to be preserved as a part of the security of the stock-holders of the Water Board. The Act of 1902 should be amended so that the Board might issue precepts for an estimated deficiency, thus obviating the delay and loss involved in precepting only when a deficiency had been ascertained and certified.

Until new charges came into operation, the deficiency

ought to be liquidated by precept and not by increased charges to consumers.

Charges for supply

Even before the 1914–18 war, and the subsequent rise in prices, the Board's charges were low as compared with those in force in many parts of the country. It was proposed that the Board should fix the rate from time to time subject to a maximum of 10 per cent. and to a condition that it should not exceed 7½ per cent. without the authority of the Ministry of Health. Consumers in areas where there was no liability to contribute towards the liquidation of deficiencies in the Water Fund should pay an additional one-half per cent.

The power to vary the rate should be accompanied by a duty to vary it in such manner as to avoid undue accumulation either of deficiency or surplus. It would be undesirable to impose this duty in such a form as to require a variation in rate by a small fraction to meet each variation in the income and expenditure estimates. On the contrary, the aim should be the maintenance of equilibrium for as long a period as possible with a rate fixed at as low a level as is consistent with sound finance. It was accordingly proposed that the Board should be under no obligation to change the rate until the surplus or deficiency was equal to a rate of one quarter per cent.

For supplies by measure, it was recommended that the existing graduated scale should be replaced by a flat rate which should be a charge per 1,000 gallons equal to the estimated average cost of all water supplied, with an additional charge of 1d. per 1,000 gallons in the non-contributory area, and that supplies for public purposes ought not to be afforded, as they were under the existing scale, at less than cost price.

The Committee suggested that rebates from the domestic rate on premises occupied solely for business purposes should be on a more generous scale.

Apportionment of deficiency

The criticism by the London County Council of the method of apportioning deficiency rates amongst the contributory authorities was examined at some length. The Committee felt that if, with revised charges, the need for a deficiency rate

as part of the Board's regular revenue disappeared in the course of a few years, it was not worth while to make any change in the method of apportionment.

Collection of water charges with local rates

The Board had on three occasions (in 1904, 1912 and 1918) considered the question of collecting their charges with the local rates, and on each occasion had come to the conclusion that such a course would be undesirable. The Committee were impressed by the grounds on which Mr. Arthur Newton, Accountant to the Board, had based his objections to the proposal, namely:

(i) The loss of the direct and complete control exercised by the Board over the collection of its income.

(ii) The adverse effect on the ability of the Board to estimate closely the amounts receivable from day to day and thus regulate their finances accordingly, which would result from the lack of uniformity in the levying and collection of local rates in different parts of the Board's area.

(iii) The risk of increased cost to the ratepayers.

(iv) The confusion and loss which would arise owing to the difference existing between local rates and water rates.

(v) The loss of valuable work done by collectors and receiving officers in furnishing information for the revision of charges.

(vi) The loss of the power to follow up cases of removal and thereby to recover amounts due which might otherwise be lost.

(vii) The inconvenience to many large consumers and others owning properties in different parts of the area by loss of the power to make payments in one sum at a central revenue office.

(viii) The fact that there was no evidence of any substantial desire on the part of local authorities for the transfer to them of the water rate collection.

A submission in favour of the proposal was put in by Mr. P. Craven, Treasurer and Accountant to the Borough of Hornsey. Briefly it was that although no great saving was likely, the change was desirable on its merits and in the general interest of the public; that it should be confined to Urban Districts,

leaving the collection in rural areas to be undertaken by the Board; and that the Board should pay a percentage allowance to the collecting authority. The view of Mr. Carson Roberts, the District Auditor, was that such a scheme "would lead to less efficient and less complete collections of the water income."

The Committee concluded that in the absence of any large saving to be expected and in view of other considerations "We do not think that a sufficient case has been made out to lead us to advocate a change from the present system of collecting water charges." They added: "We have had no evidence to show that the Local Authorities generally are anxious to undertake the work."

Programme of new works

The Committee considered the question whether the programme of works upon which the Board had entered was, in the light of the current experience, more extensive than it need have been, but came to the conclusion that the provision which the Board were making was not extravagant:

> "It is beyond question that at the time the Water Board took over the undertakings of the Companies the reservoir accommodation was not sufficient for the needs of the area. Parliamentary powers had been taken for the construction of more than one new reservoir by the Companies, but they had not at the time been started. Works were therefore needed at once to bring the undertaking into a satisfactory condition quite apart from the provision to be made for the future."

Consumption of water

Comparing the figures of consumption for the years 1912 and 1919, the Committee, whilst admitting that there was considerable uncertainty as to the population, could not resist the conclusion that there had been a serious increase in the individual user of water. They were of opinion that measures ought to be adopted to overtake the arrears in the repair of fittings and to stop waste. They pointed out that increase in individual consumption demanded as much increased provision as a corresponding growth in population would do, whilst it provided no additional revenue to meet the consequent capital and administrative charges.

Private wells

It was estimated that in respect of premises supplied by private wells, the Board lost income of about £79,000 annually, and the Committee considered a suggestion put before them that a special charge should be imposed on the occupiers of such premises.

The Committee recognised that so long as it was necessary to levy a deficiency rate, premises within the contributory area not supplied by the Board, like all other rateable property, contributed their share to that rate.

If no deficiency rate were needed, then the Committee saw no reason to impose a quasi-penalty charge on premises supplied by wells. The occupiers of such premises paid, together with other ratepayers, for water supplied for sanitary and other public purposes; like all other ratepayers, they got without charge the water necessary for the extinction of fires, but paid for hydrants and other apparatus used for the purpose as well as for any water mains specially laid to meet the requirements of the fire brigade. They did not deplete the supplies on which the Board relied, and they had to pay for the provision and maintenance of their own water supply systems.

Assessment of the Board's undertaking to local rates

The London County Council had laid evidence before the Departmental Committee as to the method of assessing the water undertakings to local rates. The Committee, however, felt that this raised a large question of rating which went beyond the scope of their inquiry.

The Committee suggested that steps should be taken for assimilating the provisions relating to water rates with those relating to the general rate.

The Board gave serious consideration to the findings of the Monro Committee.

They disagreed with the recommendation concerning the appointment of a general manager but concurred in the view that there should be some individual charged with the exercise of the functions described. The question remained as to the means to be adopted to give effect to this view. The Board felt that the proper method would be to focus their administra-

tion around their Chairman, and to make a Standing Order under which the Chief Officers would be subject to his general direction and meet him in consultation at such times as he should appoint, not being less than once a month except during vacation. Such a Standing Order was subsequently adopted.

The Board resolved that the Chief Engineer should be relieved of some of his routine duties to enable him to devote more time to general policy, that no change should be made in the method of apportionment of deficiencies in the Water Fund, and that the question of increase in individual user of water and the subject of waste be referred to the Works and Stores Committee for consideration and report.

Appropriate resolutions were passed by the Board on the lines of the recommendations of the Departmental Committee regarding revision of the charges.

CHAPTER VII

The Years of Stability

1922–1939

In the 1921 Session of Parliament the Board promoted a Charges Bill primarily with the object of carrying into effect the recommendations of the Departmental Committee.

This Bill contained various amendments to the Charges Act of 1907, designed to enable the Board to obtain the income necessary to carry on the undertaking under normal conditions without recourse to the levy of a deficiency rate and, at the same time, so to limit the charging power that in each financial year the charges for water should produce as nearly as possible the amount required to meet the expenditure for that year.

The Bill was framed to secure an equitable distribution of the burden of cost between domestic consumers on the one hand and consumers of water supplied by measure on the other. The former as a class were to pay in the aggregate the cost of the water supplied to them, the charge being based in accordance with the usual principles on the rateable value of the premises supplied and not on the quantity of water consumed. The latter were each to pay the actual cost to the Board of the water consumed.

It was proposed in the Bill that the charge for domestic supplies should be at such rate per annum as the Board should from time to time fix not exceeding ten per cent., the rate for each financial year to be fixed after consideration of the annual estimates and to be such that, so far as could be estimated, the total income on revenue account for that year would as nearly as possible be equal to the expenditure on revenue account for that year. The Board were, however, not to be required to change the rate from that operating in the previous financial year if the surplus or deficiency carried forward from that year was less than £250,000.

For water supplied by measure it was proposed that the Board should charge a uniform rate not exceeding 2s. per 1,000 gallons, this rate to be fixed at the beginning of each financial year and to be not less than the estimated average cost per thousand gallons of all water supplied in that year.

It was deemed necessary to retain the right to levy a deficiency rate although no such rate need be levied when the deficiency was less than £250,000, and provision was made for an addition to the water rates and charges in respect of supplies in the areas which did not contribute towards the liquidation of deficiencies.

Other matters upon which an alteration of the law was sought were the mode of determining rateable values, rebates on business premises, and the definition of "deficiency in the Water Fund."

The Bill was referred to a Joint Committee of the Lords and Commons, presided over by Mr. Neville Chamberlain, who amended the Bill in three important particulars. The maximum charging power of ten per cent. was accepted but the rate was not to be fixed above eight and a half per cent. without the consent of the Ministry of Health. The rebate provision was made more generous. The proposal that supplies by measure should be at a flat rate per 1,000 gallons, which met with great opposition from the traders and manufacturers of London, was rejected. In its place a scale of maximum charges was inserted which increased the 1907 Act rates by 5d. at each point in the scale with a proviso that until the Ministry directed the effective increase should be 4d. only. Any change in the domestic water rate was to be followed by appropriate revision of the scale.

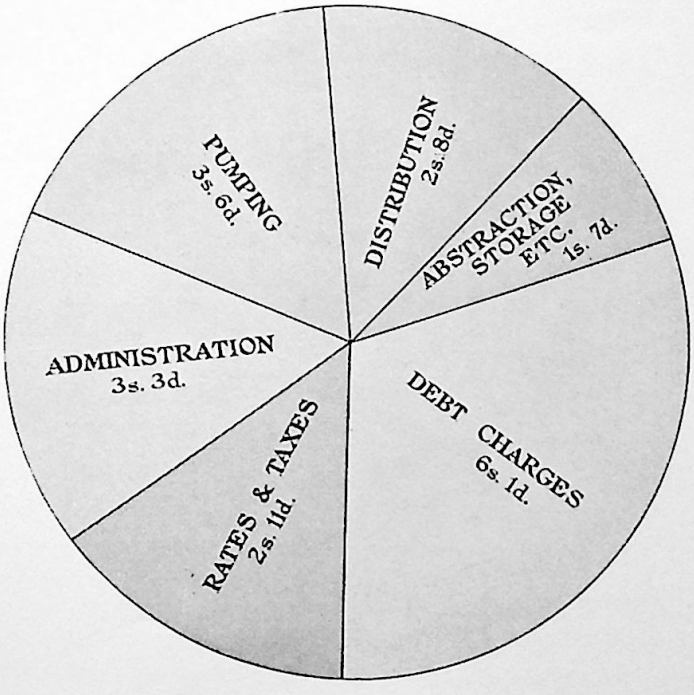
The rate per 1,000 gallons for supplies for public purposes was fixed at one eighth of a penny less than the rate or lowest rate for the time being charged by the Board under the scale for a supply of water exceeding five million gallons per quarter.

The Bill was passed in the form in which it left the Joint Committee and received the Royal Assent on 15th August, 1921 as the Metropolitan Water Board (Charges) Act, 1921, to come into operation on 1st April, 1922.

The deficiency of £1,925,338 2s. 5d. as at 31st March, 1922 was liquidated by precept.

The provisions of the new Charges Act placed the Board in a strong financial position and by 1939, prior to the beginning

THE BOARD'S SEAL 1903–1931



HOW EACH TWENTY SHILLINGS OF WATER RATE IS SPENT

NEW RIVER HEAD, 1914

of the second world war, they had been able to reduce the rate to five and three-quarters per cent. as follows:

Year ended 31st March	*Domestic water rate per cent.*
1924	7½
1925–26	7
1927	6
1928–29	6½
1930	5¾
1931	6½
1932–38	6
1939	5¾

For the years 1931–32 to 1937–38 the Board had succeeded in maintaining the rate at 6 per cent. and it appeared that provided no untoward and disturbing factor arose this stabilisation might well continue. Although on the recommendation of the Finance Committee the rate for 1938–39 was reduced to 5¾ per cent., such a deviation from what might be considered the norm could not be envisaged as continuing beyond a limited period.

In presenting the estimates for 1938–39 the Chairman of the Finance Committee pointed out that during the seven years to 31st March, 1938 the expansion of the Board's business had been met by a corresponding increase in income. There had been a substantial rise in wages and cost of materials particularly iron, steel, and fuel, of which requirements were large, and there had been a rise of over £100,000 in the annual charge for local rates. Pumping and engine charges incurred expenditure amounting in the period to some £325,000 for replacing pumping machinery, boilers, buildings and mains in large remodelling schemes. In the year 1933 the Board had undertaken the maintenance of communication pipes and the cost of that service since that date was at least £350,000. Although interest charges had shown a relatively small decrease, by the end of the period there had been an increase* in the annual debt redemption charge of £126,000 arising mainly on the acquisition debt.

* This however would be reflected in increase in earnings of the redemption fund.

Income figures showed a steady rise amounting throughout the period to rather more than £600,000 of which about one-third arose in trade consumption and two-thirds on new properties and increased assessments from rebuilding.

The approximate surplus at 31st March, 1938, of £239,000 represented an accumulation over the six years, after meeting the deficiency of £132,000 brought in at the commencement of the period.

The continuance of the rate of 5¾ per cent. depended on the prevention of an increase in expenditure exceeding the increase to be derived from new supplies and increased trade demands. It was evident that further debt charges would arise on the large sums to be borrowed for the new reservoirs and other works in hand.

On 24th June, 1938, with the darkening of the European scene, the Board approved an estimate of nearly £400,000, subject to appropriate Government grant, for the protection of the undertaking against the consequences of air attack.

In presenting the estimates for 1939–40 the Chairman of the Finance Committee indicated that the buoyancy of the income had been maintained and would support the continuance of the rate at 5¾ per cent. He felt it necessary, however, to issue a warning as to the debt position.

Out of the estimated income of £5,855,000, approximately £2,500,000 would be required to meet debt charges. During the past eighteen years the average annual expenditure on new works had exceeded £600,000; for the year 1938–39 the approximate expenditure was £1,500,000; whilst the estimate for 1939–40 was £1,700,000. The amount authorised to be spent on new works in the ensuing two or three years was £2,500,000.

In the light of these figures it was not surprising to find that the annual expenditure on debt charges had been steadily and rapidly increasing.

The necessity for the new works was recognised but it was felt that the Board should consider the desirability of deferring if possible any further new works or remodelling until existing commitments had been discharged.

The hopes raised at Munich in September, 1938, were soon shattered and in view of the international situation the Board,

on 21st July, 1939, appointed an Emergency Committee for the purpose of conducting the undertaking if and when a state of national emergency in relation to war arose, the Committee to comprise seven members as nominated with power to co-opt. For the purpose of this delegation all standing orders, regulations and orders of reference to Committees were suspended or modified as might be required.

The first meeting of this Committee on 31st August, 1939 and the outbreak of war with Germany on 3rd September, closed an era in the Board's history.

CHAPTER VIII

War and Post-War Finance

1939–1953

THE financial results for the period from 1st April, 1938, to 31st March, 1946, were as follows:

Year to 31st March	Rate per cent.	Estimated result for year Surplus + Deficiency −	Actual result for year Surplus + Deficiency −	Actual balance carried forward at end of year Surplus + Deficiency −
		£	£	£
1939	5¾	− 86,300	− 195,138	+ 66,662*
1940	5¾	− 144,100	− 428,119	− 361,457
1941	7	+ 274,650	− 41,906	− 403,363
1942	8½	+ 332,550	− 9,745	− 413,108
1943	8½	− 251,000	− 159,054	− 572,163
1944	8½	− 155,000	+ 177,538	− 394,625
1945	8½	− 148,500	− 153,098	− 547,723
1946	8½	− 206,630	+ 87,169	− 460,554

* £261,800 having been brought forward at 1st April, 1938.

The rate of 5¾ per cent. was justified for the year 1938–39. Owing to the impact of the war the actual result for 1939–40 was over £284,000 worse than the estimate which had justified the continuance of the rate.

When the estimates for 1940–41 were passed the final figures for 1939–40 were not available. Hence the full effect of the war for that year was not known and it was thought that a revision of the rate to 7 per cent. would give a surplus for 1940–41 of £274,000†. Instead of this surplus, however, the actual result was a deficiency of £42,000, an adverse turn of £316,000. The total deficiency carried forward therefore exceeded £400,000.

† For convenience, most of the figures which follow are given in round thousands.

It will of course be appreciated that such disparity between estimated and actual results was inevitable. When the annual estimates for any financial year are prepared approximate figures only for the previous year are available, the actual figures not being ascertained until some months later. In a rapidly deteriorating situation it is highly probable that estimates, being prepared partly in the light of the happenings of the previous year will err on the side of optimism. This is what happened in the early years of the war.

In auditing the accounts for 1940–41 the District Auditor drew attention to the fact that the deficiency carried forward to the ensuing year exceeded the limit of £250,000 laid down in section 8 of the Charges Act of 1921. He noted in the Balance Sheet, however, that in considering this deficiency he had had regard to a sum of £200,000 appearing on the liabilities side of the balance sheet under the heading "Special Funds—Working Capital." This amount had been set aside out of surplus profits not legally distributable by the late metropolitan water companies and transferred to the Board. In the view of the Auditor this was revenue money and should be brought into account in determining the deficiency. In effect, for the purposes of section 8 of the Charges Act, the deficiency was £203,363 only and the statutory requirement was satisfied.

The Auditor repeated his note on the subsequent balance sheet and took the amount of £200,000 into account each year up to 1944–45.

For the year 1941–42 it was necessary for the rate to be raised to 8½ per cent., the maximum figure to which it could be raised without the consent of the Ministry of Health. It was hoped that with this rate in operation the deficiency brought forward at 1st April, 1941, would be largely liquidated and that the deficiency carried forward at the end of the year would be under £100,000. It soon became apparent, however, that this expectation would not be realised and that a rate of 8½ per cent. was inadequate.

In order to clarify the position before the annual estimates for 1942–43 were presented, discussions took place in December, 1941, and January, 1942, with Ministry officials as to what steps ought to be taken in the matter. This action was the more relevant as in the previous September the Minister had asked

all water authorities and companies not to increase their charges without prior reference to him.

The Board's case was that although it was true that the statutory limit of the charging powers had not been reached an increase in the rate beyond 8½ per cent. would impose upon consumers charges which they could not reasonably be asked to bear. These consumers had remained to brave the many difficulties and anxieties of the time and they ought not to be expected in their reduced numbers to shoulder the whole burden of increasing costs and falling income, some part of which should be passed on to be borne by larger numbers in happier times.

The Ministry were granting substantial financial aid to Metropolitan Borough Councils in order to prevent further increases in local taxation and as the Board were affected by the same circumstances as those which were handicapping the Borough Councils, it was felt that there was no sound reason why similar help should not be given to the Board.

As a result of the discussions with the Board's representatives the Minister was satisfied that some financial assistance should be afforded to the Board. As such assistance was not given to any authority unless it was in overdraft to some extent, it was considered not unreasonable to ask the Board to carry an overdraft of £250,000, the amount of deficiency which they were empowered to carry forward, any deficiency in excess of this amount to be met by cash advances from the Ministry as non-interest bearing loans repayable on such terms and conditions as might be agreed after the war.

Advances of £200,000 and £160,000 were received before the close of the financial year. A repayment of £150,000 was made in December 1942 as the actual result for the year to 31st March, 1942 was better than was forecast when the advance of £160,000 was received.

In order to keep the "effective" balance carried forward below the figure of £250,000 an amount of £42,678 awarded by the Court of Arbitration in 1904 for the repair of a defective culvert, and hitherto held as a special fund, was transferred to revenue account as at 31st March, 1942 together with £6,000 provision for bad and doubtful debts which was no longer required.

When the annual estimates for 1943–44 were presented it appeared that the approximate deficiency to be carried forward at 31st March, 1943 was £565,236 and the Ministry acceded to an application for a further advance of £105,000. When the accounts for 1942–43 were closed, however, the actual deficiency was found to be £572,162 10s. 9d. To reduce this deficiency to the statutory figure of £250,000 it was necessary, after taking notice of the working capital balance of £200,000, to supplement the Board's own revenue by bringing into account £122,162 10s. 9d. out of the advance by the Ministry.

Under section 18 of the Act of 1902, any revenue surpluses during the first 20 years after the Appointed Day were to be paid into a Special Redemption Fund for discharging loans raised for the acquisition of the companies' undertakings, for which a period of 100 years was fixed by the Act. Since the period of 20 years elapsed, annual contributions on an accumulating basis have been made from revenue account to the Fund. The Metropolitan Water Stock Regulations, 1903, provide, however, that revenue account shall be relieved annually from the Special Fund, by 1/80th of the amount in the Fund at 31st March, 1923, for the year 1923–24; by 1/79th of the amount remaining in the Fund at 31st March, 1924, for the year 1924–25; and so on during the 80 years to 31st March, 2003.

In February, 1943, an unofficial approach was made to the Ministry on the question whether the Special Redemption Fund, which then exceeded £950,000 and from which the annual relief was still meagre, could be partly used to relieve the abnormal situation caused by the war. The effects of the air raids on London had been to reduce substantially the net annual value upon which the Board raised its income and there was no early prospect of the position being materially changed. It seemed that this was the sort of exceptional circumstance in which the Ministry might be asked to accelerate the relief lying untapped in the Special Redemption Fund. It was suggested that the transfer of £500,000 to revenue account would be appropriate.

The reply of the Ministry after close and sympathetic investigation was that certain legal difficulties made the proposition unacceptable. Even if this were not so a Defence

Order would be necessary and the Ministry would not be disposed to take such a step.

For the year 1943–44 there was an unexpected surplus of £177,000 instead of a deficiency estimated at £155,000, the deficiency carried forward at 31st March, 1944 being only £394,000. This was due largely to a favourable revision of the rates of wear and tear allowance for income tax, the charge to tax for the year being £81,000 as compared with an estimate of £254,000, whilst there had been some recovery of income. In July, 1944 it was possible on the approximate result for 1943–44 to repay the Ministry £210,000.

When the accounts for 1944–45 were balanced the deficiency to be carried forward at 31st March, 1945 was £547,722 16s. 7d. This result had been foreshadowed when the annual estimates for 1945–46 were prepared, the approximate figure being £518,000 and in March the Ministry made a further advance of £163,000.

To reduce the deficiency of £547,722 16s. 7d. to the statutory limit it was again necessary to bring into account part of the Ministry advance, *viz.* £97,722 16s. 7d.

For 1945–46, largely due to recovery in income, there was a surplus of £87,000 instead of an estimated deficiency of £206,000 and only £10,554 4s. 1d. was required to be taken out of the Ministry advance which stood at £268,000.

The loss of rateable value which occurred during the war years had its effect upon the revenue of the Board and, as already indicated, on certain occasions the deficiency on revenue account would have exceeded the statutory limit of £250,000 had the Board been entirely dependent upon their own resources. That such a situation would inevitably arise unless increases were made in the water charges was foreseen in 1942 when, with the object of obviating any such increases which might be necessary, the Minister of Health arranged, as a temporary expedient only, to make cash advances out of which the revenue deficiency in excess of £250,000 might be met.

Following his audit of the accounts for 1944–45 the District Auditor commented:

> "Whilst the steps taken to tide over a difficult transitory period may be outside the statutory provisions relating to the Board's revenues,

there can be little doubt that they were reasonable and warranted when considered in the light of the altogether exceptional circumstances for which immediate provision had to be made."

The figures of income and expenditure from 1939 to 1946 were as follows:

Year to 31st March	*Rate per cent.*	*Income*	*Expenditure*
		£	£
1939...	5¾	5,553,600	5,748,738
1940...	5¾	5,463,876	5,891,995
1941...	7	5,994,641	6,036,547
1942...	8½	6,419,442	6,429,187
1943...	8½	6,543,824	6,702,878
1944...	8½	6,818,317	6,640,779
1945...	8½	6,766,005	6,919,103
1946...	8½	7,045,539	6,958,370

In 1939–40 the Board were affording domestic supplies at fixed rates to premises of an aggregate net annual value of about £72,500,000. There were non-domestic charges in force amounting to some £128,000 whilst garden supplies were yielding £87,000 per annum.

At 1st April, 1945, the net annual value chargeable with fixed domestic water rate was approximately £64,500,000, a drop of about £8,000,000 in assessment, due almost entirely to the removal from rating of premises destroyed by enemy action. Despite an all-round increase in 1940–41 of about 25 per cent. in non-domestic and garden charges these items were providing only £115,000 and £56,000 respectively, a decline in the former of £13,000 and in the latter of £31,000 per annum. In the case of metered supplies, losses through the destruction of premises supplied were offset during the war years by the largely increased consumption of water due to the manufacture of munitions.

It was estimated in November, 1945, that the maximum amount by which the annual income would be increased, if the 1939 position could be restored and the existing charges maintained, would be over £1,000,000 and that the total loss in cash during the war years was £5,920,000.

The increase in expenditure for 1944–45 over 1938–39 was approximately £1,200,000. This was due mainly to those factors associated generally with war conditions such as rises

in price of materials, including fuel, and the imposition of purchase tax, payment of wartime bonuses on wages and salaries, the rise in local rate poundage and income tax, and air raid precaution requirements.

For the year 1946–47 it was possible to maintain the rate at its war-time level of 8½ per cent., but by the end of that year it was evident that this would be insufficient to provide enough revenue without incurring a deficiency. Costs were rising sharply and in addition the increasing consumption of water involved considerably increased expenditure both in the revenue working expenses and in the debt charges borne by revenue account. Furthermore, the Board were faced with a very large programme of repair and reconstruction of existing works, a large part of which had fallen into arrear during the war but required to be undertaken if the supply was not to be put in jeopardy. In his "budget" speech introducing the estimates for 1947–48 the Chairman of the Finance Committee said:

> "As to the future, in present circumstances, it is almost impossible to make any reliable forecast. All I can say is that the Finance Committee are not unhopeful that the rate at the suggested new level (9 per cent.) will produce income sufficient to meet prospective expenditure, but that is entirely dependent on the present generally inflationary tendency being checked and the reasonably speedy replacement of net annual value lost through the War."

Unfortunately those two factors did not operate in favour of the Board. The rise in costs and prices, although somewhat abated, was not halted and hopes of an early revaluation of properties to bring them into accord with current values of money did not materialise. In consequence it was necessary to increase the rate from 9 to 10 per cent. for the year 1948–49 at which level it has since stood except for the two years 1950–51 and 1951–52, when it was reduced to 9¼ per cent. The rate of 10 per cent. fixed for the year 1952–53 is the maximum which the Board are empowered to charge.

Methods of Financing

The war brought about changes in the methods of financing the undertaking by way of borrowing.

To provide money for capital purposes the Board may issue

Stock under the Metropolis Water Act, 1902, and the Metropolitan Water Stock Regulations. Under powers contained in the Metropolitan Water Board Act, 1906, they may issue mortgage loans and bills, the latter of a currency not less than three and not more than twelve months.

Under the Act the Board were required to make regulations governing the issue of bills and in their regulations they included the provision that tenders should be received and opened by the Bank of England and that bills should be issued by and payable at the Bank.

Provision of the necessary borrowing powers is of course antecedent to these issues, such powers being conferred by the Board's private Acts or by sanction of the Ministry.

Being deemed by section 32 of the Metropolitan Water Board Act, 1931, to be a local authority for the purposes of section 3 of the Local Authorities (Financial Provisions) Act, 1921, the Board have sanction from the Ministry to borrow temporarily for current revenue purposes up to a maximum at any one time of £2,000,000.

So far as the issue of stock was concerned the pre-war practice was simple. Under the Act of 1902 the rate per cent. had to be fixed in consultation with the Governor of the Bank of England. When it was proposed to make an issue the actual procedure was for the Bank to be consulted generally as to terms. The Government broker was brought into the matter and subject to an order of the Ministry consenting to the creation and issue of the class of stock, the rate of interest, the date of redemption, the description of the stock, the method of transfer and the mode of redemption, the necessary arrangements were made with the Bank of England to manage the issue and arrange for the underwriting.

Mortgage loans were arranged direct with the lenders and formed an easy, convenient and cheap way of raising capital money.

The issue of bills was made by direct arrangement with the Bank.

It was possible therefore to provide capital cash to meet expenditure more or less as it was required, issues of bills following one another in increasing amounts, each repaying

the previous one and providing additional cash for further expenditure until it was thought necessary to replace this temporary form of borrowing, which could not in any case exceed £2,000,000 at any one time, by the more permanent form of mortgage loans or stock. Such an arrangement was economical, there being no large amount of capital cash awaiting use for any length of time incurring unnecessary debt charges.

There were in all 25 issues of bills at varying average rates of discount, the lowest being 11s. 9d. for the 25th issue on 1st March, 1939 (£1,000,000 for six months), and the highest £6 2s. 6d. issued in New York on 18th September, 1916, (6,400,000 dollars — £1,343,126 19s. 4d. for twelve months).

In 1938, the Board's powers to issue bills were limited by the action of the Bank of England in consultation with the Committee of the Clearing Bankers. During a period of easy money there had been an increasing tendency in the money market to encourage municipal borrowing on short term. Many local authorities were induced to finance themselves in the London money market by creating floating debts by the issue of bills at six or twelve months placed directly in the market and by means of loans granted by the market against a receipt with a covering letter wherein the borrower undertook if required to provide a mortgage on the rates as security.

Much of this paper had been used by the market to secure loans from non-clearing bankers and when a crisis occurred a large amount was in the hands of the banks who had recourse to the Clearing Bankers.

Whilst normally the banks were prepared to give full facilities to local authorities who were their clients, granting loans in anticipation of the receipt of rates, they did not wish to encourage the practice whereby local authorities, especially those which were small and had no national credit standing, maintained a floating debt.

The Committee of Clearing Bankers decided that clearing banks would not accept municipal bills or other municipal short term paper as security for money market loans unless such paper were eligible for discount at the Bank of England.

The Bank of England decided that until further notice they would in their dealings with the discount market, regard as

eligible for discount and as security for advances, bills of local authorities and public bodies where the issues satisfied certain conditions. These conditions provided that the currency of such bills should be limited to a period not exceeding six months and that for at least 60 consecutive days, or two periods of not less than 30 consecutive days each, during each financial year commencing after 12th December, 1938, the authority or public body should have no bills outstanding.

The Finance Committee viewed with concern the action of the Bank in imposing conditions which, in effect, materially restricted the exercise by the Board of powers conferred upon them by Parliament. The matter was brought to the notice of the Minister of Health, who, however, took no action.

The Board were of course under no obligation to appoint the Bank as their agents for the issue of their Bills and they were at full liberty at any time to amend their regulations and to authorise any other bank to carry into effect the issue of the Bills. The fact, however, that in such circumstances the Bank of England would not have been prepared to discount such bills if they did not comply with the new conditions would probably have had an adverse effect on the terms at which the issue could be made.

The new conditions were applied rigidly by the Bank and the war brought no relaxation.

In the case of issues of stock and mortgage loans wartime controls were exercised through the Capital Issues Committee of H.M. Treasury and the Public Works Loan Board.

In 1940 the Treasury expressed the desire that local authorities should utilise fully all available internal resources to meet expenditure on capital works before resorting to external borrowing.

Article 11 of the Metropolitan Water Stock Regulations provides that in the exercise of their borrowing powers the Board may apply moneys in the redemption funds, with certain exceptions, instead of raising cash by the creation and issue of additional stock. By 31st March, 1952, the amount of redemption fund moneys so applied since 1940 was £2,000,700 of which £897,800 was replaced by Metropolitan Water (F) Stock, 1971–76, and £369,700 has been repaid.

DEBT POSITION

The debt position as at 31st March, 1952, is shown below:

	£
Total issues of stocks, loans and bills	73,286,012
Stock cancelled and loans and bills repaid ...	15,150,219
Stock and loans outstanding	58,135,793
Redemption fund moneys utilised for capital purposes, outstanding	733,180
	£58,868,973

Redemption and sinking fund moneys in hand amounted to £3,688,725, leaving a net debt of £55,180,248, for which provision had still to be made.

During the period to 31st March, 1952, £509,867 had been contributed from Revenue to Capital Account.

CHAPTER IX

Schemes Inherited by the Board

1904–1913

On 24th June, 1904, the undertakings of seven of the eight metropolitan water companies and those of the Urban Districts of Enfield and Tottenham were vested in the Board. The remaining undertaking, that of the New River Company, followed on the 25th of the next month.

The companies at the time were flourishing and, with the exception of the Kent Company whose supply was derived entirely from wells, and the Chelsea Company, whose area was completely built over, were either engaged in or contemplating major works. This activity was due in great measure to the Balfour Royal Commission of 1892–93 whose report vindicated the rivers Thames and Lee as sources of supply in regard to both quality and quantity. The Commission had also approved the large storage reservoir schemes presented to them by the Engineers of the Grand Junction Company (for the Thames) and the Engineer of the East London Company (for the Lee). Moreover, the Llandaff Commission of 1897–99 supported the Balfour Commission and rejected distant sources of water supply on financial grounds. Confidence in the two rivers had thus been restored after a period of doubt which had started early in the century.

The two Urban Districts derived their supply from wells and were, by 1902, partly dependent on the New River and the East London Companies. They had been seriously worried at their future prospects and during the proceedings on the London Water Bill had asked for their undertakings to be transferred to the new Board.

The companies supplied from the Thames and the Lee had, with the backing of the report of the Balfour Commission, obtained authority within the last few years for the construction in the two valleys of storage reservoirs and works in connection

therewith. The East London Company obtained three Acts in the years 1894, 1897 and 1900, the effect of which was to exhaust the sites for storage reservoirs in the Lee valley. When the Board took over, the works under the Company's Act of 1897 (the Banbury and Lockwood Reservoirs) had just been completed and much of the land for the two reservoirs authorised under their Act of 1900 had been acquired.

The New River, Grand Junction and West Middlesex Companies had formed the Staines Reservoirs Joint Committee who obtained powers in 1896 to construct two reservoirs at Staines, together with intake works and an aqueduct connecting the intake works with a distribution reservoir. From the distribution reservoir the water gravitated to the Grand Junction and West Middlesex works at Hampton. The reservoirs had been completed and orders were given for filling them in May, 1902. No water, however, had yet been drawn from them.

The New River Company were actively engaged in completing a scheme, authorised by their Act of 1897, to enable them to bring their share of the Staines reservoirs' water to their district. This scheme consisted of two large storage reservoirs and twelve filter beds at Kempton Park, with a pumping station thereat for raising water from the Staines Aqueduct to these reservoirs and for pumping filtered water. A 42-inch trunk main 17 miles long was to connect the works to covered reservoirs at Fortis Green on the Company's western boundary, with a repumping station and balancing reservoirs at Cricklewood along the line of the 42-inch main. The Kempton Park works, the main as far as Cricklewood, and the pumping station there, were in course of construction.

The Lambeth Company had obtained an Act in 1900 enabling them to construct a reservoir of 1,000 million gallons' capacity at Island Barn, Molesey, but they had not started on its construction by 1904.

Lastly, the Southwark and Vauxhall Company had obtained statutory powers in 1894 for the construction of a covered reservoir for filtered water at Honor Oak, and in 1898 for the construction of a large storage reservoir on the site of Apps Court, Walton, to be connected to their Hampton works by a tunnel under the Thames. When the Board took over, the land for the covered reservoir had been purchased and brick

kilns for making bricks from the clay on the site had been set up in 1898. The Company had invited tenders prior to the appointed day, but by reason of the imminent transfer of the undertaking to the Board, the directors did not feel justified in committing the Board to expenditure in respect of this work and no action had been taken on the tenders received. A contract for the construction of two storage reservoirs on the Apps Court site had been let to Messrs. John Aird and Sons in February, 1901, and the ceremony of turning the first sod was performed by Sir Henry Knight, the Chairman of the Company, on 30th April of that year.

The land at Apps Court had been held of the King, since the time of Edward II at least, by the customary tenure of "free alms," consisting of a barrel of ale and a quarter of corn made into bread and distributed to the poor on All Saints' Day, for the souls of the Kings of England. When the Company acquired the land in 1898 they tried to ignore the tenure but were eventually compelled to transfer £200 of £2 10s. per cent. annuities to the Charity Commissioners as a commutation.

The Board were, therefore, faced with major works from the start and it will perhaps be as well to follow these works through before describing the Board's own schemes. It will be seen that the Board decided to continue with the works already in hand and eventually adopted also those schemes which although authorised were then only on paper.

By the end of the year 1904 the Board had decided to bring the Staines storage reservoirs into active use instead of leaving them merely as a bank to be drawn upon in time of drought. Water was first drawn for the purpose of supplying the Western district on 28th December, 1904.

In April, 1905, the completion of the Staines (New River) communication works was approved, and in September of that year a tender for constructing the balancing reservoirs at Cricklewood was accepted. Tenders for providing the iron pipes for the 42-inch iron main from Cricklewood to Fortis Green and for building the covered reservoirs at Fortis Green were accepted in June and July, 1906. The contract for laying the main was let in March, 1907.

In the meantime the reservoirs and pumping station at Kempton Park had been completed and water was first taken from the Staines aqueduct for filling the Kempton Park reservoirs on 30th April, 1906. In order to test the new pumping engines and to get the filter beds into thorough working order it was necessary to pump water by means of a special connection near Kempton Park into the Eastern district Thames supply main. This main, 36 inches in diameter and 19 miles long, was completed in 1872 by the East London Company and connected the Company's Hanworth Road filtration works to the reservoir in Finsbury Park. On 3rd December, the Sunbury intake (constructed by the Company) was closed for that purpose and the pumping station and works at Kempton Park were used for the first time. The experiment proved a success, the new engines performing their work remarkably well and showing considerable economy over the Cornish engines at Hanworth Road works. The pumping plant consisted of three triple expansion engines for pumping the filtered water, and two triple expansion engines for raising the Staines reservoirs' water from the aqueduct.

The two reservoirs at Fortis Green, the two balancing reservoirs at Cricklewood, and the 42-inch main from Cricklewood to Fortis Green, were completed in 1908, well within the 15 years allowed for the work under the New River Company's Act of 1897. The supply from the Kempton Park works direct to the New River district started in July, 1908.

Under the New River Company's Act of 1897 powers had been granted to construct a pumping station at Fortis Green and in December, 1911, the Board approved a scheme involving the building of stations here and at Cricklewood, in order to improve the supply to the "Kidderpore" zone.

The recently established Hampstead Garden Suburb was within this zone as also were large tracts of land which only three years before were agricultural but, as the result of opening up the railway to Golders Green, had now become residential. Hendon was also growing rapidly.

The supply to this district was afforded by pumping from the Barrow Hill pumping station, near Regent's Park, to the Kidderpore reservoir in Platts Lane, Hampstead, and to the high levels to the north of it.

In times of great demand it was difficult to give adequate pressure at these levels and to Hendon on account of the loss of head through friction in the existing small mains, which were over three miles long.

Under the scheme the Fortis Green station, which was to be built on a site adjoining the Cranley Gardens station of the then Great Northern Railway, was to supply Hampstead and Highgate reservoirs and, in case of emergency, the Hornsey Lane reservoir above the Archway Road. The proposed Cricklewood station, which was to be built next to the engine house there, was to supply Cricklewood and the Kidderpore districts.

Diesel oil engines were proposed for both stations instead of steam engines. To enable the Board to arrive at the comparative cost of upkeep of these two types, the Chief Engineer gave the approximate cost of pumping one million gallons of water 100 feet high (fuel and labour only) as follows:

	£	s.	d.
Diesel oil engines (assuming oil at 42s. per ton and two drivers)		18	9
Steam engines (assuming coal at 18s. per ton, two drivers and two stokers)	1	18	4

A saving in pumping charges of some 50 per cent. was therefore anticipated by using diesel engines.

The tender of Mirrlees, Bickerton and Day, Ltd., was accepted in May, 1912, for six four-cylinder vertical engines, each of 160 brake horse power at 200 revolutions per minute, driving through gearing horizontal three-throw ram pumps. Three of these engines were installed at Fortis Green and three at Cricklewood, the Cricklewood engines being brought into use in September, 1914, and the Fortis Green engines in November of the same year. They were the first large diesel engines used by the Board for pumping and have given very reliable service since. The Cricklewood engines were capable of pumping four million gallons a day to the Shoot-up Hill or Kidderpore reservoir zones, while the Fortis Green engines were capable of delivering the same amount of water to the Highgate and Hampstead reservoirs. The Cricklewood diesels were supplemented by the installation of electric pumps in 1939 and 1945. The steam plant at this station was also supplemented by the installation of further electric pumps

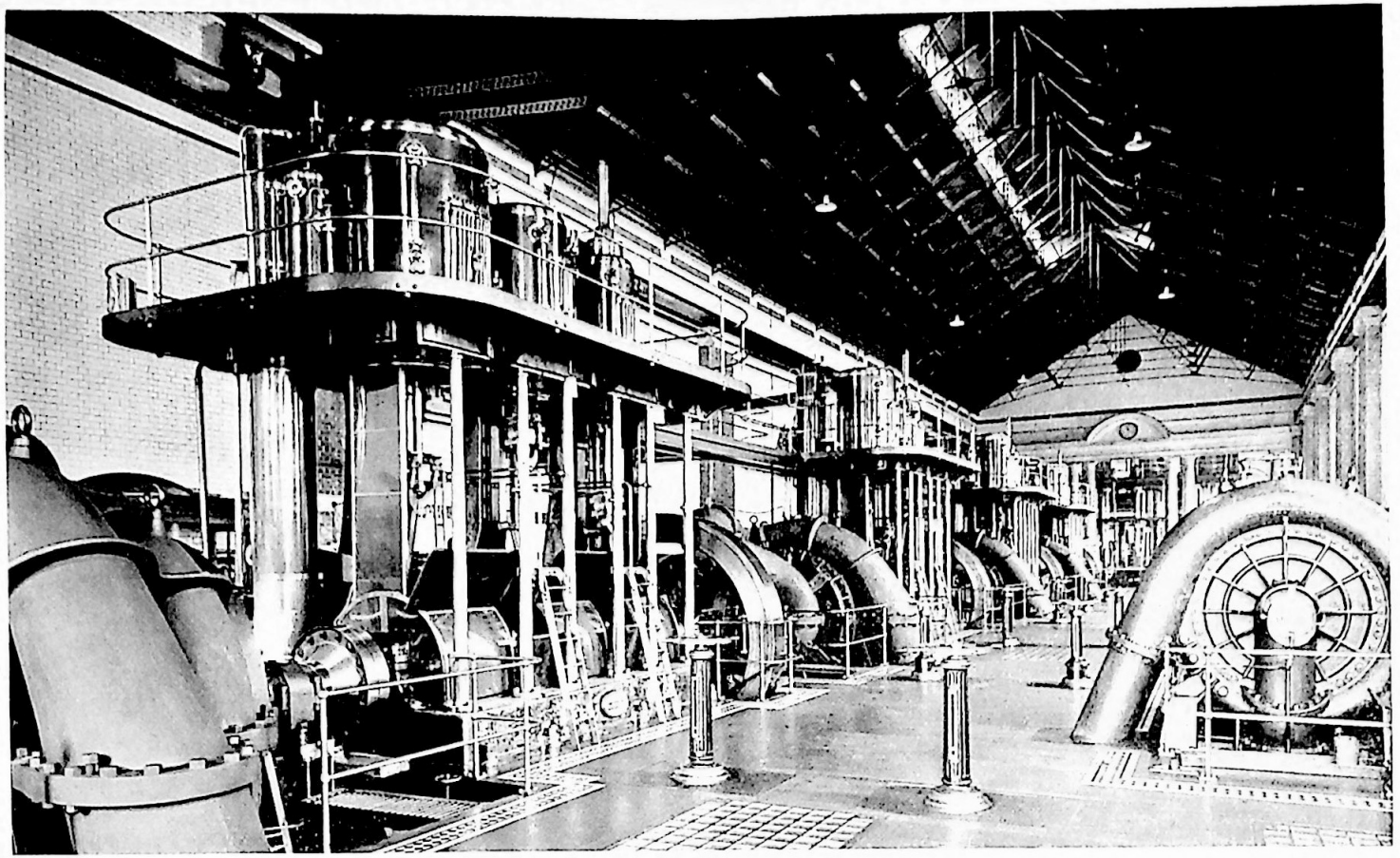
in 1951. At Fortis Green station another four vertical oil engines driving centrifugal pumps were supplied by W. H. Allen & Sons, Ltd., in 1935. In March, 1947, the Board authorised the installation of three electric pumps for supplying the Southgate reservoir head and two similar pumps of smaller capacity for the Hampstead and Highgate heads. This installation was completed in the summer of 1952.

Work on the two storage reservoirs at Walton proceeded without interruption and in May, 1905, the contract for the intake works, by means of which the water would be abstracted from the river, was let to John Aird & Sons, who had constructed most of the former companies' works. In the same year a tunnel under the Thames containing two 48-inch mains leading from the reservoirs to the Hampton works was completed.

On 13th April, 1907, the reservoirs were inaugurated by the Chairman of the Board, Sir Melvill Beachcroft. They were named the "Knight" and "Bessborough" reservoirs after Lord Bessborough, one of the Directors of the Southwark and Vauxhall Company, and Sir Henry Knight, the Chairman of the Company at the date of transfer. The Knight or Western reservoir has a capacity of 480 million gallons and a water area of 51½ acres; the Bessborough or Eastern reservoir has a capacity of 718 million gallons, and a water area of 74 acres. The work entailed 1½ million cubic yards of general excavation, the use of the same quantity of material to form the embankments, the provision of 200,000 cubic yards of puddle and 75,000 cubic yards of Portland cement concrete. The lining of the reservoirs contains nearly 2½ miles of coping. The cost of the work was approximately £419,000. The whole of the works were designed and superintended by Mr. J. W. Restler, the former Engineer to the Southwark and Vauxhall Company, who had been appointed the Board's deputy chief engineer in 1905.

At first the reservoirs were filled by pumping from the nearby intake of the former Chelsea Company. The Act of 1898 which had authorised the construction of the reservoirs had also authorised the construction of a pumping station for filling them,

WALTON, SHOWING THE FOUR NEW FILTER BEDS



RAW WATER PUMPING MACHINERY, WALTON

but the company had not taken any further steps with regard to this prior to the Board taking over. In August, 1905, the Board decided to go forward with this part of the scheme and authorised the erection of the machinery and the engine and boiler houses. Almost three years elapsed, however, before any of the work was put in hand. During that time the scheme was reconsidered by the Chief Engineer with a view to concentrating in one building the pumping arrangements required in that neighbourhood, thus effecting a large saving in revenue charges, and giving effect to the policy adopted by the Board of passing all water through reservoirs before filtration (see page 254). The arrangement necessitated an increase in pumping plant and an enlargement of the station buildings.

The Thames Ironworks Shipbuilding and Engineering Company, Ltd., of Greenwich, supplied the machinery, and Dick, Kerr & Co., Ltd., were responsible for the buildings. The engines were started on 10th June, 1911, by the Rt. Hon. John Burns, M.P., then President of the Local Government Board, and an ex-member of the Board. The main pumping machinery consisted of four triple expansion engines of 2,000 horse power collectively, each engine driving a centrifugal pump capable of pumping 25 million gallons a day. In order to make use of the surplus head of the water in the Walton reservoirs flowing by gravity to Hampton, arrangements were provided whereby the water which was being drawn off could be passed through hydraulic turbines in the engine house, the power developed being employed to pump river water into the Knight reservoir together with that from the main pumps. It was estimated that stored water being drawn off would give enough power to lift at least a third of its bulk of river water into the reservoir. Three hydraulic turbines were, therefore, erected in the engine house, each of 150 horse power. Raw water is delivered from the pumping station through two 54-inch mains into the Knight reservoir whence it is allowed to flow into the Bessborough reservoir, from the eastern extremity of which it is drawn off and conveyed by means of two 48-inch pipes to the tunnel previously referred to. Provision was also made for the machinery at the pumping station to deliver raw water to the Island Barn reservoir (see next page), situated about 1½ miles to the south-east of the station. The steam engines, running at 120 revolutions

per minute, have been working almost continuously for the last 42 years.

We now turn to the Lambeth Company's proposed reservoir at Island Barn, so named on account of the Island Barn Farm, which formerly existed on the site of the reservoir and which was completely surrounded by rivers, the Ember and the Mole.

Until the passing of the Thames Conservancy Act, 1911, the Board possessed a complicated bundle of rights relating to abstraction from the Thames based on agreements made between the companies and the Conservators and on statutory provisions. The Lambeth Company, under their agreement with the Thames Conservancy were allowed to take 24½ million gallons a day from the Thames without restriction and another 7½ million gallons a day from the gravel, making in all 32 million gallons a day. By their Act of 1900 a further daily average of 20½ million gallons, based on half-yearly periods, could be taken by the company from the Thames when the flow over Molesey weir was not less than 190 million gallons per day, the maximum abstraction in any one day not to exceed 100 million gallons. From 10th July to 31st August of the year 1906, when the matter was considered, there had been only seven days when the flow of the Thames had exceeded 190 million gallons and consequently very little additional water could be taken from the river through the Lambeth intakes. During the previous two years also a considerable quantity of water had to be pumped from the Southwark and Vauxhall division into the Lambeth division. The population of the Lambeth division, moreover, was estimated in 1906 to have increased by 118,750 since 1900, and at that time was increasing more rapidly than in any other of the Board's districts.

In view of these circumstances the Chief Engineer recommended that the construction of the Island Barn reservoir should be proceeded with at the earliest possible moment, in order to take better advantage of the abstraction rights under the 1900 Act. Moreover, he considered that this reservoir, when completed, would fall in with any future arrangement just as efficiently as the Staines reservoirs or the Walton reservoirs, and that it was essential whatever decision the Board might come to on the

general question of sources of supply. He estimated that it would take five years to complete the reservoir.

On 8th November, 1906, the Board sanctioned the necessary expenditure and tenders were subsequently invited for the work which included a 54-inch main from the proposed pumping station at Walton. In their Various Powers Bill of 1907, the Board sought an extension of time for the construction of the reservoir but met with considerable opposition. An extension of seven years was eventually granted but the area of the reservoir had to be curtailed and the design modified to meet objections raised by local authorities. The work was undertaken by Robert McAlpine and Sons.

On 24th October, 1908, in the presence of the Rt. Hon. John Burns, M.P., President of the Local Government Board, the Chairman of the Works and Stores Committee, Mr. Charles E. Hearson (member of the Board for Camberwell Borough Council) performed the ceremony of cutting the first sod. He had on the same day laid the foundation stone of the Walton pumping station.

The reservoir was inaugurated on Saturday, 4th November, 1911, by the Lord Mayor of London, the Rt. Hon. Sir T. Vezey Strong, a former member of the Board, who named it the "Island Barn" reservoir. He was accompanied at the ceremony by the Rt. Hon. the Lord Mayor of Dublin, the Rt. Hon. the Lord Mayor of Cardiff and the mayors of metropolitan boroughs and provincial cities. These gentlemen, all in their robes of office, made an impressive array.

The reservoir holds 922 million gallons and has a water area of 121 acres. The embankment is 1 mile 1,200 yards long and contains $1\frac{1}{4}$ million tons of earth taken from the inside of the reservoir. The 54-inch main, 1 mile 1,200 yards long, enables water to be delivered from the Walton station, and is connected to the mains at Molesey, formerly belonging to the Lambeth and Chelsea companies. In addition, water can be gravitated from the Knight and Bessborough reservoirs at Walton, the top water level of the Island Barn reservoir having been kept at a somewhat lower level for the purpose. After storage the water passes through large diameter mains to the filter beds at Surbiton. The reservoir was originally designed by Mr. T. F. Parkes, Engineer to the Lambeth Company, who died in 1907,

but it was redesigned by the Chief Engineer, Mr. Bryan, who directed its construction.

The next major scheme to be considered is that of the East London Company under their Act of 1900. This Act authorised the construction of two reservoirs in the valley of the Lee and by 1906 practically the whole of the land, about 980 acres, had been acquired for both reservoirs. The borings necessary to test the site proved that the London clay existed over the whole of the area. In October of that year the Chief Engineer urged the necessity for completing without delay one of the reservoirs in order to safeguard the supply to the Eastern district and to ensure an adequate supply to the New River district. In advising this course Mr. Bryan was influenced by the following factors. During the months of August and September it had been necessary to take no less than 1,550 million gallons from the then existing storage reservoirs and even in mid-October the reservoirs were still being depleted although for some weeks past about four million gallons a day had been pumped into the Eastern district by means of intercommunication works.* The whole resources of the Eastern district from wells and from its Thames supply had been in use and for a number of weeks consecutively 19 million gallons per day had been obtained from wells in the district. Moreover, the population of the Eastern district had increased by 157,000 since 1900 and it was thought that at the end of the time which would elapse during the construction of the reservoir—five years—the population might further increase by 100,000.

The Chief Engineer considered the construction of the reservoir to be absolutely necessary whether the supply were taken in future from the Thames or the Lee and that it was actually required at that time. If water from the storage reservoirs in the Thames valley were transferred to the Eastern

*The intercommunication works, as they were called, were carried out mainly with the object of assisting East London, the Achilles' heel of the Board's area. They are still in use today and constituted the first step in the process, which the Board have consistently pursued for 50 years, of integrating the distribution networks of the eight separate water companies.

district it would be necessary to construct a new conduit, the cost of which and of the machinery and filter beds would equal that of the proposed reservoir. (This plan, to pump raw Thames water by means of a large main to the Lee valley, was to be adopted many years later.) The Wales scheme, if implemented, would take 20 years to complete. Assuming that great extensions were made in the Thames valley or an auxiliary supply were obtained from Wales the new reservoir would still be necessary to safeguard the supply to the Eastern district. The Board, therefore, in November, 1906,determined to proceed with the construction of one of the reservoirs and in January, 1908, accepted the tender of Charles Wall, Ltd., of £340,770 therefor. Mr. E. B. (later Sir Edmund) Barnard, M.P., (member for Hertfordshire County Council) who was then Chairman of the Works and Stores Committee, performed the ceremony of cutting the first sod on 11th April, 1908.

The construction of the reservoir necessitated the diversion of the river Lee, the construction of a number of bridges, and the provision of an effluent channel to carry off surface water drainage.

The site was a common marsh which is said to have been used by the commoners of Chingford for the pasturage of their cattle from the days of the Conqueror down to 1906 when the common rights ceased. Prior to the cattle being permitted on the marsh they were marked by the marsh reeve or the assistant marsh reeve. The occupiers of land in the marsh had certain rights of cutting grass there, and this and the pasturage were regulated by rules drawn up and agreed to in the Old Vestry for the guidance of the commoners and reeves.

In 1910, the question as to the type of pumping machinery to be installed was considered. It was bound up with the available abstraction from the river Lee. Besides the natural fluctuations in the flow of the Lee, which were considerable, drainage operations had tended to bring down the flood water much more quickly than formerly, and so, by making the low water period longer and the high period shorter, rendered it necessary to provide for the abstraction of large volumes of water when the flow permitted. This meant providing for a total pumping capacity of not less than 180 million gallons in 24 hours. After careful enquiry into various

types of pumping plant a contract was entered into with the Pump and Power Company, Ltd., for the installation of five "Humphrey" gas pumps at the northern end of the reservoir. The system of pumping was a distinct departure from all ordinary methods of raising water, requiring no steam cylinders, crank shafts, connecting rods, fly-wheels, etc., but, acting on the principle of the internal combustion engine, merely an explosion chamber, certain pipes connected to the reservoir, and the necessary building to cover the plant.

On Saturday, 15th March, 1913, His Majesty King George the Fifth, accompanied by Her Majesty Queen Mary, inaugurated the reservoir and named it "King George's" reservoir. This was the first of the Board's reservoirs to receive a Royal inauguration.

The reservoir now has a capacity of 2,729 million gallons and occupies about 420 acres, the perimeter being 4½ miles. A short embankment which was constructed across the centre to prevent excessive wave action during high winds has three openings giving free access for water to each side. Water from the Lee, after being pumped into the reservoir at the northern end, flows gradually to the outlet tower at the southern end. From this tower it descends into a tunnel under the embankment which leads into an open channel connecting the reservoir to a distributing basin at Chingford Mill. From Chingford Mill the water flows through the Walthamstow chain of reservoirs to the aqueduct joining them to the Lee Bridge works. In 1934, 7-foot and 5-foot conduits were constructed linking the reservoir to the Lee Bridge aqueduct, which brings stored water to the filtration works. This allows the reservoir to operate free of the Walthamstow group of reservoirs.

We now come to the immense covered reservoir at Honor Oak, preparations for the construction of which had been started by the Southwark and Vauxhall Company under their Act of 1894. Powers to complete this reservoir were obtained by the Board in their Act of 1906. The contractors were J. Moran & Son, and the total cost of the reservoir, including land, amounted to approximately £236,000.

The reservoir was inaugurated on 5th May, 1909, by the then Lord Mayor of London, Sir George W. Truscott, accom-

panied by the Lady Mayoress. Some 1,500 guests from local authorities, provincial water undertakings and engineering institutions attended. The reservoir was at that time, and possibly remains, the largest covered reservoir in the world constructed at one time and under one contract. It is divided into four sections each capable of being filled or emptied independently. It is constructed on the natural clay formation, the bottom being of concrete formed as inverted arches crossing each other at right angles. The outer retaining walls of the reservoir are of concrete lined on the inside with brickwork. The retaining wall varies in thickness at the base from 6 feet to 16 feet according to its depth. The reservoir measures 824 feet in length between the walls with a maximum width of 587 feet and occupies an area, including banks, of about 14½ acres, the actual water area being about 10 acres. Its total capacity is about 56½ million gallons. Large quantities of materials were used in the construction. The number of bricks amounted to over 16 million, all made on the site from the clay taken out of the excavations. 95,000 cubic yards of concrete were used in the foundations, walls, floor and covering of the reservoir, and the quantity of cement employed amounted to 20,000 tons. The quantity of excavation below the natural surface of the ground amounted to 173,000 cubic yards, whilst over 14,000 cubic yards of clay were used in the puddle wall, etc. The works gave employment to an average number of about 400 men over a period of three years.

The principal object of the reservoir was to afford low pressure service to the south-eastern portion of the Board's area but by means of mains under the Thames it has long been possible to transfer the supply to the north of the river when necessary. The top water level of the reservoir is 143 feet above O.D. The bottom of the main body of the reservoir is at an elevation of 121 feet 6 inches above O.D., the depth of water being 21 feet 6 inches. A portion of the north-eastern section is 12 feet 6 inches deeper than this, the greatest depth of water being, therefore, 34 feet. The reservoir was originally supplied from a 42-inch pipe connected to the Board's 42-inch main which conveys filtered water from the pumping station at Hampton to the Nunhead reservoirs, a distance of about 17 miles.

The whole of the works were designed and carried out under

the supervision of Sir James Restler, and the reservoir was named the "Beachcroft" reservoir after Sir Melvill Beachcroft, the first Chairman of the Board.

These then were the principal works initiated by the companies and finished by the Board. Reference to the second large reservoir in the Lee valley, authorised by the East London Company's Act of 1900, has been omitted here, because it was not started until many years later (see page 132). The next chapter deals with schemes initiated by the Board.

CHAPTER X

Future Supplies

1905–1930

THE Board waited a year after taking over the undertakings before embarking on what they considered their next most important duty—second only to the maintenance of the existing supply—namely that of safeguarding the future supply of water to the Metropolis. In July, 1905, the Chief Engineer was instructed to report on the adequacy of the Board's sources of supply and this report was laid before the Works and Stores Committee in December, 1906. Mr. Bryan's report was to have a profound effect on the Board's policy and it is therefore necessary to set down his more important conclusions. They were:

Firstly, that by reason of the whole of the former eight undertakings being in the hands of one authority, it was now possible to make use of the various resources in a more economical manner, and consequently the construction of a new reservoir in the Lee valley, to contain about 3,000 million gallons, and the interchange of water between the Eastern and New River districts would permit the postponement of the second reservoir sanctioned by the East London Waterworks Act of 1900.

Secondly, he confirmed the finding of the Balfour Commission that the Thames Basin was quite capable of yielding 300 million gallons a day if adequate storage were provided, but added that this would by no means exhaust its capabilities.

Thirdly, that the bringing into use of the recently completed Walton reservoirs in 1907, and the Island Barn reservoir about 1913, would enable the Board to meet all requirements until about the middle of 1917. It would, however, be necessary to seek powers in 1909 or 1910 to enable additional works to be started in 1912 and finished by the middle of 1917, at which date the demand would have overtaken the capabilities of the then existing reservoirs to

afford a full supply. Before 1909 the Board would have to investigate the relative merits of two schemes, the one for constructing reservoirs of moderate capacity in progressive stages as may be required by the increase in population, the other for the construction of one great reservoir in the valley of the Enborne of a capacity of 15,000 million gallons and capable of being increased to any extent up to 55,000 million gallons by raising the embankment.

Fourthly, that it would be necessary for the Board to consider at some future period, and long before the date when the supply from the Thames Basin would be overtaken, the question of obtaining supplemental supplies from mid-Wales.

A special sub-Committee examined this report, and in November, 1907, their conclusions on the "Future Water Supply of the Metropolis" were presented to the Board. In their report the following table showing the increase in the water supply to London during the previous 25 years appeared:

Year	*Average daily supply*	*Estimated population*	*Gallons per head per day*
1881 ...	143,821,037	4,331,619	33·20
1886 ...	154,911,895	4,930,854	31·41
1891 ...	175,408,632	5,232,155	33·52
1896 ...	197,988,052	5,606,920	35·31
1901 ...	215,069,948	6,235,293	34·49
1906–07 ...	225,000,683	6,851,045	32.84

The daily average of 225 million gallons was derived as follows:

	Gallons
River Thames	128,842,695
River Lee	44,150,290
Springs and Wells	51,355,797
Gravel beds	564,008
Hampstead and Highgate Ponds (non-domestic) ...	87,893
	225,000,683

Over 57 per cent. of the whole was derived from the Thames.

The Balfour Commission had estimated that the following quantities of water could be obtained within the watersheds of the Thames and Lee:

Source	*Average daily supply*
Wells in Kent ...	27½ million gallons
River Thames ...	300 ,, ,,
River Lee	52½ ,, ,,
Wells in Lee valley	40 ,, ,,
Total ...	420 ,, ,,

With regard to the Thames supply the total daily quantity from this source (including gravel beds) was, under the most favourable physical conditions and having regard to the existing statutory restrictions, 228½ m.g. This figure included 51 million gallons "excess water" which by statute could only be taken when the daily flow of the river exceeded the following volumes at the places named or if the abstraction did not reduce the flow below these volumes:

Molesey Weir ...	190 m.g.d.
Penton Hook Weir ...	285 ,,
Bell Weir	250 ,,

Although the authorised daily abstraction amounted to 228½ million gallons it was impossible to make the most of this right until sufficient storage reservoirs had been constructed. The works already in existence, together with those authorised by Parliament, would not be sufficient for the purpose.

The question of obtaining additional supplies from the river Thames largely resolved itself, therefore, into the question of the construction of additional reservoirs.

With regard to the river Lee the position was that after reserving a daily quantity of 5,400,000 gallons for the navigation the whole of the remaining water of the Lee was absolutely vested in the Board. The Chief Engineer considered that when the construction of one of the reservoirs already sanctioned in the Lee valley was finished, the works of the Eastern district would, during a dry period similar to that which occurred in the years 1901–03, furnish a daily average supply from the river Lee of 23 million gallons. During a similar period the New River district would derive 22½ million gallons a day from the Lee thus making a total, during a period of exceptional drought, of 45½ million gallons a day.

With regard to wells in the Lee valley Mr. Bryan considered the estimate of the Balfour Commission (namely that 40 million

gallons daily could be obtained from the wells and springs in the valley) reasonable. As to the wells in Kent, the Commissioners had estimated a yield of 27½ million gallons a day. This district differed from others by reason of there being no storage reservoirs and consequently the demands greater than the average which occurred during the summer could only be met by having a certain proportion of wells in reserve. A further 7 million gallons a day could be relied on throughout the year from wells in the Board's Southern district.

The total estimated yield from these sources other than the Thames amounted therefore to 120 million gallons a day. (45½ + 40 + 27½ + 7.)

The amount of water to be provided in the future depended on two factors: (1) the size of the population, and (2) the amount of water consumed per head of the population per day.

The Balfour Commission had assumed a population (based on the trend of the time) of 11¼ millions to be supplied with water by the metropolitan water authorities in 1931. On the same basis the Llandaff Commission had estimated a population of 12 millions by 1941. The Works and Stores Committee in their present report envisaged the necessity of supplying 16,286,000 in 1960.

The Balfour Commission had assumed a consumption of 35 gallons per head per day and the Llandaff Commission adhered to this figure. On the other hand Sir Alexander Binnie, the Chief Engineer to the London County Council, had considered that figure the least quantity that should be estimated and he had preferred to make it 40. The actual consumption in 1907 was only 32 or 33 gallons per head, but the Works and Stores Committee preferred to follow the Balfour figure.

Applying the two factors of population and consumption, and having regard to the assumed rate of growth of the population, the following results were obtained:

Year	*Estimated population*	*Estimated average daily supply* m.g.
1921	8,703,000	305
1931	10,221,000	358
1941	12,000,000	420
1960	16,286,000	570

It was estimated that in the year 1916 a quantity of 106.5 million gallons a day would be obtainable from all the then sources of supply other than the Thames, a figure which could only be increased subsequently to 120. On the other hand it was anticipated that the supply from the Thames could be increased from 174.5 million gallons in 1916 to 450 million gallons in 1961, an increase of 275.5 million gallons. The following estimates of gross quantities of storage required in order to provide the increased supply were therefore presented to the Committee:

Year	*Average daily supply from Thames*	*Gross total storage required**	*Amount of such storage per million gallon average daily supply*
	m.g.	m.g.	m.g.
1916 ...	174.5	6,436	36.88
1921 ...	196	9,886	50.44
1931 ...	244	17,534	71.86
1941 ...	300	27,276	90.92
1954 ...	400	44,862	112.15
1960 ...	450	54,059	120.13

*Thames storage in existence in 1907, or authorised by Parliament and the Board, amounted to 7,279.5 million gallons.

Neither of the Royal Commissions had expressed an opinion as to the ultimate amount of water to be derived from the the Thames, but the Chief Engineer considered that an average daily quantity of 450 million gallons could be obtained from that source and that the works then in existence and authorised would be sufficient to last until 1917. Various schemes had been considered for giving an increased supply but the Committee emphatically supported the conclusions of the two Royal Commissions that the Thames would for many years provide a pure and adequate supply of water for the consumers of London. In view of the possibility, however, of the Thames reaching its limit by 1960, they considered it essential to examine the practicability of acquiring some supplemental gathering ground. Other authorities were promoting legislation almost yearly for acquiring watersheds, and if nothing were done on behalf of London it might result in all suitable areas being allotted

to other bodies. It was not considered unreasonable to provide for the year 1960 because, in the first place, the necessary works for bringing the water to London from a distant source might well take 20 years to construct and, secondly, there was a limit beyond which existing sources were incapable of expansion and that limit was within measurable distance of time.

This report was considered by the Board on 6th December, 1907, when they resolved to seek Parliamentary powers enabling them to provide additional supplies from the Thames for as long a period as was economically practicable. Instructions were therefore given for the necessary scheme to be prepared.

Considerable time was spent on the preparation of the scheme and it did not come before the Board until March, 1910. In the meantime the opportunity had been taken to examine the Enborne and the "Progressive" schemes.

Three schemes based on the valleys of the Kennet and Enborne had been prepared by Professor Henry Robinson in 1899 for the Lambeth Company, and a similar one had been placed before the Balfour Commission. The original idea was to construct a reservoir to be filled by gravitation from the Enborne and by pumping from the Kennet, water being discharged into the river Thames (*via* the Enborne and Kennet) in times of drought so that additional quantities of water would be available for abstraction lower down the river, whether at Hampton or elsewhere. The reservoir was intended to act solely as a compensation reservoir. The great advantage which a storage reservoir scheme possesses, namely purification by storage, would be entirely lost by allowing the stored water to flow down and mix with the raw water. The Chief Engineer investigated, however, the practicability of constructing such a reservoir in the neighbourhood proposed by Professor Robinson and of providing conduits by means of which the stored water could be brought to London. The geological experts consulted were of opinion that the condition of the valley was eminently suitable and that the necessary embankment could safely be constructed at or near the site selected. A pumping station at Pangbourne would eventually be required to pump Thames water into the reservoir in order to make full use of it.

It was decided to investigate further for the purpose of comparing the relative value of such a scheme with one for constructing further reservoirs in the Thames valley—the "Progressive" scheme. The following estimates were the result:

Estimated cost of the Enborne scheme

	£
First instalment, available 1916 or 1917. Of sufficient capacity to provide water required up to 1925, including reservoirs, filter beds, conduits, pumping machinery, proposed covered service reservoir and lands ...	3,637,560
Second instalment. To be ready by 1925, to provide water until 1933	2,150,500
Third instalment. To be ready by 1933 and to provide water until 1941	2,608,760
	£8,396,820

Estimated cost of the "Progressive" scheme

	£
First instalment. To be available by 1916 or 1917. A reservoir, 5,200 million gallons capacity. Sufficient to provide water up to 1924. Including filter beds, conduits, pumping machinery, proposed covered service reservoir and lands	1,983,760
Second instalment. To be available by 1924. A reservoir, 5,500 million gallons capacity. Sufficient up to 1931	1,713,640
Third instalment. To be available by 1931. A reservoir, 3,500 million gallons capacity. Sufficient up to 1934	674,080
Fourth instalment. To be available by 1934. Two reservoirs, each 3,350 million gallons capacity. Sufficient up to 1941	1,902,230
	£6,273,710

In comparing the relative costs of the two schemes, the estimates comprised every expenditure from the intakes on

the rivers up to and including the proposed covered service reservoirs.

The estimated cost of the Enborne reservoir with all appurtenant works for filling the reservoir, etc., was £1,976,760 while that of the reservoirs for the "Progressive" scheme was £3,211,600 but the distance of the Enborne reservoir from the proposed covered service reservoir being more than three times that from the pumping station of the "Progressive" scheme, caused the total cost of the scheme to be much greater.

After full consideration the "Progressive" scheme was preferred as being more advantageous. The scheme would enable the Board not only to meet the demands of a growing population but also to avoid any unnecessary expenditure should the growth of population not attain the proportions which had been foreshadowed.

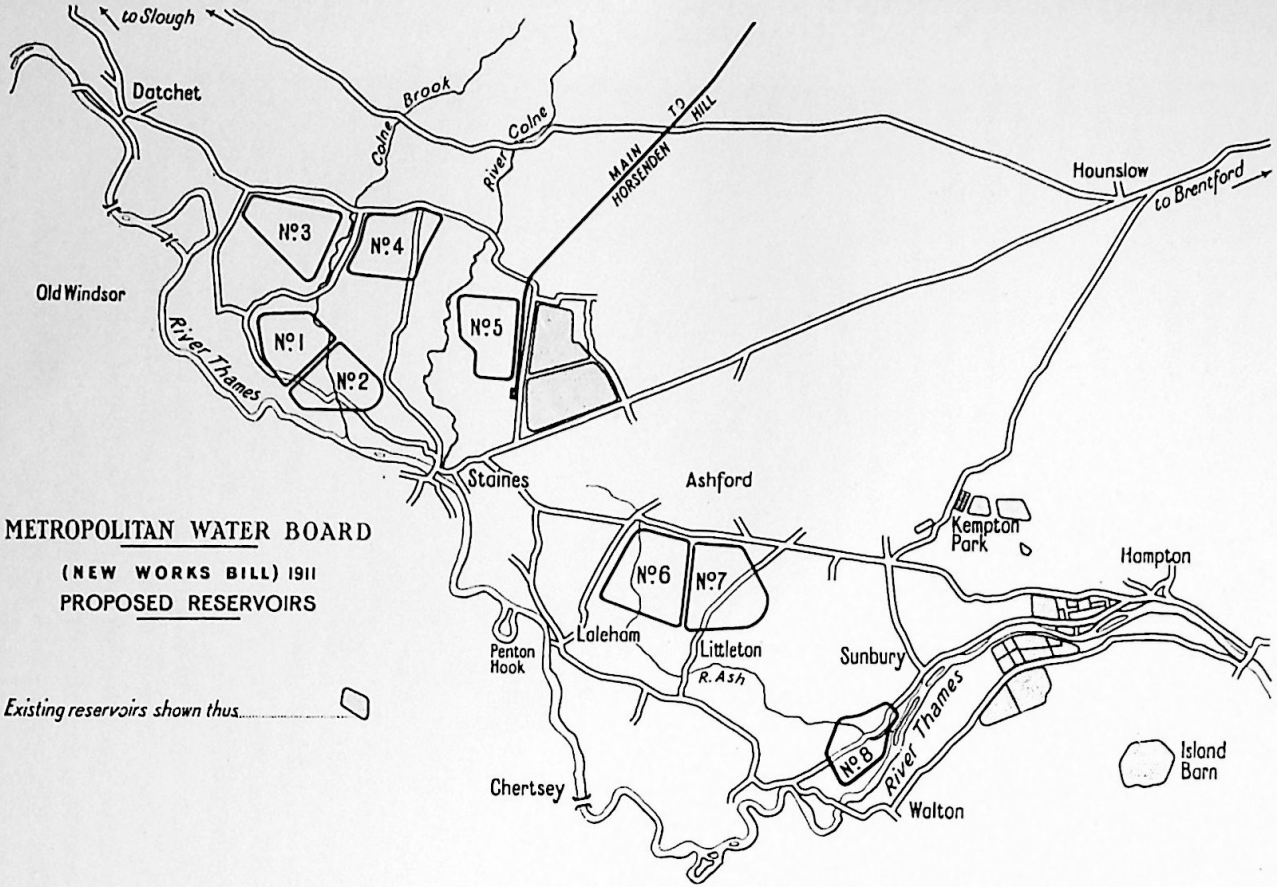
The results of the investigations of the Director of Water Examination on the subject of storage (see page 242) clearly proved that with sufficient storage and with all due precautions observed with regard to filtration and distribution, a uniformly safe and wholesome water supply could be secured without going to a distant source.

A scheme was also outlined for modifying the distribution system when the first instalment of the "Progressive" scheme was completed, one of its principal suggestions being that Chelsea and part of Westminster, which had been supplied from the south side of the river ever since the Chelsea Company's intake was moved to Surbiton in 1856, should be supplied from the north side, thus leaving available an extra 20 million gallons a day for the Southern district.

Since the Board desired to be informed of the expenditure which would be required to provide for the further period to the year 1961 rough estimates taking into consideration differences of sites and positions of works relative to the centres of distribution had been prepared. According to these estimates the approximate cost of the Enborne scheme to provide 150 million gallons a day extra from the Thames after 1941 would be £9,573,000, and of the "Progressive" scheme, £7,958,000.

Approval to the scheme for the construction of reservoirs in progressive stages in the Thames valley was finally given by

INAUGURATION OF THE ISLAND BARN RESERVOIR, 1911,
By the RT. HON. SIR T. VEZEY STRONG, K.C.V.O., LORD MAYOR OF LONDON



PROPOSED RESERVOIR SITES, 1911

the Board in April, 1910, when the preparation of a draft Bill was ordered.

Proposed Reservoirs

On 16th December the draft Bill was approved by the Board. Powers to construct eight reservoirs were sought, Nos. 1 to 4 in the Horton, Wraysbury, Ankerwyke district, No. 5 opposite the more northerly of the two Staines reservoirs, Nos. 6 and 7 north of the village of Littleton and No. 8 along the riverside just south of Sunbury (see plan opposite).

A number of petitions alleged that the scheme would prejudice the amenities of the River Thames and it was represented to the Board that many petitioners who were public authorities would welcome an opportunity of discussing the whole matter with the Board. A meeting took place with those authorities on 15th March, 1911, when the scheme was fully explained and discussed. A strong appeal was made that the Board should abandon reservoir No. 8 which it was proposed to construct on the banks of the river opposite Walton, and set back the banks of reservoirs Nos. 1 and 2 proposed to be constructed near Ankerwyke and Hythe End. The Law and Parliamentary Committee, who had organised the meeting, decided that since all parties represented the public they would accede to this appeal and therefore, in accordance with the authority conferred upon them by the Board, they stated that reservoir No. 8 would be withdrawn from the Bill and that Nos. 1 and 2 reservoirs would be reduced so as not to be nearer than 600 feet from the Thames.

The fear that large reservoirs would mar the beauty of the countryside was very much in people's minds at that time but when it is seen how the scenery has changed since those days it is realised that far from these reservoirs destroying the amenities, they now prevent further encroachment. Birds of many kinds appear to appreciate the protection afforded and they have become an endless source of fascination for nature observers. (See the photographs facing pages 288 and 289.)

The Bill came before a Joint Committee of the House of Lords and the House of Commons on 29th March, 1911. The Committee were unable to agree to the construction of Nos. 1 and 2 reservoirs and very considerable objections were

raised against Nos. 3 and 4. The Board considered that by striking out Nos. 1 and 2 the whole scheme had been to a certain extent unbalanced. In particular, Nos. 1 to 4 formed a group with a common pumping station and intake which had been designed to serve this part of the scheme as a whole. The Board therefore decided to abandon Nos. 3 and 4.

The objection of the Joint Committee to the scheme is well explained in a statement made by the Chairman (Lord Kintore) when the Board were on the point of withdrawing the Bill altogether in view of the Committee's decision to fix the minimum flow for abstraction purposes at 170 million gallons a day (see Abstraction from the River Thames, page 154.) He said ". . . You must remember, Mr. Balfour Browne (the Board's Counsel), that you came to Parliament with a scheme of such magnitude, that had it been allowed in its entirety you would have been free from all Parliamentary control for 30 or possibly it might have been 40 or 50 years. It would I consider have been difficult and indeed improper, for any Joint Committee of Parliament to have placed you in such a position. That being so, it is for you to consider whether in any future application, similar considerations are not likely to weigh with any Committee before whom you are set. In our view the terms we offered were equitable and ample to provide storage and a supply of water for the next 21 years, long before when, if necessary, the Board could have applied for additional provision."

The Bill eventually received the Royal Assent on 18th August, 1911. The powers that were left after the passage of the Bill through Parliament embraced the construction of storage reservoirs Nos. 5, 6 and 7, covered reservoirs for filtered water at Barn Hill and Horsenden Hill and a main connecting these latter reservoirs to filtration works at Staines, also authorised by the Act.

On 17th May, 1912, the Board considered a report on future supplies having regard to the passing of the Act. The report on the Census of 1911 had just been published and it was evident from the population figures that the first instalment of the works would not require to be of the size anticipated in the Chief Engineer's earlier reports and that subsequent instalments could be deferred as experience dictated. The

Census, however, only gave the night population and did not include those people who, residing outside the Board's area, were engaged in business within it and therefore had to be supplied by the Board during the day. It was now considered safer to estimate future needs by ignoring the factor of growth of population and concentrating on the actual increases in the daily quantity of water supplied, especially during the summer months. The relevant statistics were as follows :

Year	*Daily average supply.*	*Daily average supply in June, July, August and September.*
	m.g.	m.g.
1881 ...	143.8	161.7
1891 ...	175.4	189.6
1901 ...	215.1	236.3
1911 ...	239.9	269.7

Between 1901 and 1911 the daily average supply throughout the year had increased by 24.8 million gallons and in the summer months the increase was as much as 33.4 million gallons daily. The average daily supply during the week ending 28th July, 1911, exceeded 300 million gallons. If the calculation for the storage required in 1927 were based upon the actual increase in consumption during the summer months of 1911, as compared with 1901, and upon conditions of flow in the Thames similar to those of the drought of 1899, the approximate volume of reservoir accommodation required in the Thames valley would be some 14,600 to 15,000 million gallons, of which the Board already possessed about 7,000 million gallons.

The report, after defining the Board's liability with respect to certain potential areas of supply, proceeded to describe the scheme recommended for the supply to the area north of the Thames. This comprised the construction of reservoirs 6 and 7 with a joint capacity of 7,000 million gallons and supplied from a new intake to be constructed below Penton Hook. They would discharge into the Staines Aqueduct which would conduct the water to the Kempton Park station where it would be filtered.

Reservoirs 6 and 7 were chosen in preference to No. 5, near the Staines reservoirs, because the construction of this

latter reservoir would have entailed an intake above Penton Hook Weir.

These reservoirs would give an additional quantity of storage in excess of that immediately required and therefore the purchase of the land for both reservoirs was recommended. It was considered that the construction of No. 7 only need be proceeded with immediately and that No. 6 could be commenced two years later. The Chief Engineer found that the borings which had recently been made on the site of reservoirs 6 and 7 were geologically satisfactory, that the site was an economical one and that no other situation between Penton Hook and Teddington Weir offered equal advantages.

The complete new scheme fell into three sections. Firstly, reservoir No. 7, with pumping stations at Littleton and Kempton Park; an intake at Laleham; filter beds at Kempton Park and trunk mains. This section should be completed by the end of 1917. Secondly, reservoir No. 6 at Littleton. Thirdly, reservoir No. 5 near the Staines reservoirs, and filter beds there of about 25 acres. In the Chief Engineer's opinion these three sections would suffice for the supply until the year 1932.

The anticipated cost of the scheme, which was limited to the north side of the river, was as follows:

	£
First section	1,646,400
Second ,, ...	635,000
Third ,, ...	950,500
Mains, etc.	250,000
	£3,481,900

As will be seen later, the third section of the scheme was never implemented in the form outlined here and the others soon underwent considerable modification.

The Board were informed that further proposals had been made by the Chief Engineer for safeguarding the supply to the south side. These were of a much smaller order, not exceeding £350,000 in cost and depending upon Chelsea and Westminster being supplied from the north side of the Thames instead of from the southern district as hitherto.

At their meeting on 14th June, 1912, the Board authorised the construction of reservoirs Nos. 6 and 7 and gave instructions for the preparation of a full report with plans, estimates, etc., for the construction of No. 7 reservoir at Littleton, together with the necessary intake, filtration and distribution works.

On 26th July, 1912, however, the Board decided that reservoirs Nos. 6 and 7 should be constructed together. The reasons for this change were that the clay was found to be distributed over the two sites in such a manner that the puddle clay required for the walls of reservoir No. 6 could be more economically obtained from the site of reservoir No. 7 and that much additional expense and inconvenience would arise if the two reservoirs were constructed under separate contracts, with two firms engaged upon the same ground.

It was decided to defer for the time being consideration of the pumping plant at Kempton Park and Laleham until actual experience had been obtained of the "Humphrey" pumps then being installed at Chingford and the Diesel oil engines ordered for the Cricklewood, Fortis Green and Green Street Green stations.

The estimated cost of constructing the two reservoirs together was £1,650,200, including conduits and river diversion, pump houses and intake works, all of which were to be included in one tender.

In November, 1913, the Board applied to the Thames Conservancy for their approval of the new intake works as laid down in the Board's New Works Act of 1911 and the Thames Conservancy Act, 1911. The consent of the Conservancy was reported the following month.

The tender of Dick, Kerr & Co., Ltd., the lowest of 14 submitted for the construction of the reservoirs, was accepted on 24th July, 1914. This tender covered everything except the engine house buildings, of which the foundations alone were provided for.

The tender price for the construction of reservoir No. 6 amounted to £378,404 and that of No. 7 £225,100, compared with £630,000 and £605,000 respectively estimated by the Chief Engineer in July, 1912, and £396,210 and £256,447 in June, 1914. The Chief Engineer had, in his 1912 estimate, included venturi meters, recorders, sluices, planting the banks,

etc. Moreover, when preparing his original estimate, the ground had not been proved by boreholes which were later sunk and revealed favourable conditions resulting in diminution of constructional cost. It was realised in July, 1912, that close calculations could not be made until detailed surveys had been completed, but it was considered impracticable to postpone the estimate until the Board were in a position to invite tenders as, in the meantime, the land and easements would have to be acquired and other expenditure incurred in preparing the contract.

When Mr. Restler succeeded to the office of Chief Engineer, following the death of Mr. Bryan on 28th October, 1914, he reconsidered the design of the reservoirs and made proposals for constructing the two reservoirs as one. This entailed omitting the central embankment and substituting training walls to ensure that the entire contents of the reservoir would be in complete circulation which was now, as a result of the researches of Dr. A. C. (later Sir Alexander) Houston, considered to be of the greatest importance in promoting the purity of the supply. Other features of his proposals were the shortening of the intake and outlet channels, one outlet tower instead of two, and the necessary mechanism for drawing off the water, either at the surface or at any lower point, as might be expedient from time to time.

The construction of the work as one reservoir instead of two would postpone the date at which the water would be first available for supply but it was not then anticipated that the completion of the entire works as altered would greatly exceed the four years allowed for the construction of the first reservoir.

At the request of the Water Examination Committee the question of equalising storage, in its relation to the Board's Thames valley system, was also considered and an understanding was arrived at that the supplies from the Littleton and Staines reservoirs should be so arranged as to be drawn upon as equally as possible, so that the storage periods in all the Thames reservoirs might be similar, due regard being had to periods of drought and the avoidance of double pumping. It is interesting to note that in 1916 Dr. Houston, the Director of Water Examination, introduced the practice of chlorination

on a large scale, which was to reduce considerably the importance then attached to equalisation of storage.

On 19th March, 1915, the Board decided to vary their contract with Dick, Kerr & Co., Ltd., in order to effect the above alterations.

A suitable labour force had to be recruited and arrangements made for their welfare. It was in keeping with the times that the Board in March, 1915, decided to contribute £150 towards the cost of erecting a mission hall for the use of the workmen engaged on the construction of the new reservoir. They also agreed to pay £100 per annum to the Navvy Mission Society towards the salary of a missionary to be employed amongst the men engaged on the works and this arrangement continued until the work was almost completed. The contractors on their part agreed to pay a similar sum towards the hall and the salary of another missionary from the Society.

By January, 1916, the labour difficulty on the contract had become acute, and there was now little chance of it improving before the end of the war. Attempts had been made to attract labour by increasing rates of wages and granting war bonuses. Efforts made to import Irish labour had met with little success. Of the 2,000 to 2,500 men required to complete the work only about 500 had been at work during the year. The contractors had three large Lubecker excavators, but it had only been possible to man two for a few weeks and only one had been in commission for the last two months. At the same time trouble was being experienced with quicksand.

In February, 1916, the Ministry of Munitions ordered Dick, Kerr & Co., Ltd., to cease work on the site, but it was necessary for a considerable number of men to be employed for a few weeks longer in order to complete partly finished works which would otherwise have caused flooding or danger. The power station had also to remain at work so that the underground water could be kept down until such time as valuable plant had been brought above water level. The value of the plant on the site amounted roughly to £100,000 and 20 miles of rails had been laid. The works had also to be measured so that there should be a complete record of the state of the work at the time of closing down.

Questions subsequently arose between the Board and the

contractors as to the legal effect of the Government order upon the contract and the Board eventually started an action in the High Court for a declaration on the matter.

In the Court of first instance, Mr. Justice Bray decided that the contract was merely suspended by the act of the Ministry of Munitions. The Court of Appeal, however, reversed this decision by holding that the service of the notice terminated the contract. Having regard to the importance of the matter and to the large sums involved the Board considered that they had no alternative but to take the case to the House of Lords, whose decision, given on 26th November, 1917, upheld the view of the Court of Appeal.

Sir James Restler died on 4th November, 1918, a week before the Armistice. Immediately after the Armistice the Clerk of the Board was instructed to make application for the removal of the war-time restrictions on the construction of the reservoir.

On 28th March, 1919, Mr. H. E. Stilgoe, M.I.C.E., formerly City Engineer of Birmingham, was appointed Chief Engineer to the Board. At the same meeting the Board were advised that the completion of the reservoir would probably take another five years, assuming labour conditions to be favourable. It appeared that of the £1,650,200 authorised, a balance of £1,458,200 was left. Revised estimates were prepared, which showed that payment to a contractor for the completion of the reservoir would then amount to about £1,058,000. Pumping machinery would cost £250,000, and other charges, £112,000. Even so the cost of completing the whole of the works was expected to be less than the amount of the unexpended balance. This was explained by the fact that it had been found practicable to omit works intended to improve circulation, estimated at £237,000, which were inserted in the original estimate at the suggestion of the Water Examination Committee who later consented to their omission.

It was now considered impossible to obtain satisfactory contracts on the old basis of a lump sum or fixed price and that the contract should be on a cost plus fixed amount of profit basis, as recommended by the Treasury Standing Committee. In that event, in lieu of profit on a percentage basis, the contract would contain a provision for the payment to the contractor

of a definite sum to cover profit, provision of plant, etc., and the successful tenderer would be the one quoting the lowest sum under that head. The contract should also include an estimate by the Board of the probable cost of completion, namely, £1,058,000 with a clause allowing the contractor one-fourth of any saving effected on this sum. The estimated sum would be affected by variations of wages, prices of materials and alterations in the works.

As to the works to be carried out, further alterations to the original design were approved. These included alterations to the two baffle banks, reducing the width of the puddle and altering the lining to the inner slopes of the main embankment, and other details.

Tenders were invited from selected contractors for completing the work and the lowest, that of S. Pearson & Son (Contracting Department), Ltd., quoting a lump sum payment of £191,500 for plant and profit was accepted on 20th June, 1919. This company had constructed the Banbury and Lockwood reservoirs, Walthamstow, for the East London Waterworks Company at the beginning of the century.

When the work was abandoned in 1916, no part of the embankment had been completed, but a length of about 670 out of a total of 6,925 yards of trench had been excavated and filled in with puddle clay under the site of the northern embankment.

The geological formation of the site is London clay of great depth, overlain by gravel beds of an average thickness of 18 feet and surface soil of 3 feet. Early in 1920, when the trench for the western puddled clay core was being excavated, running sand of great depth was encountered and it was decided to move the western embankment to a position about 300 yards to the eastward, and to compensate for the curtailment of the area of the reservoir which this involved by an alteration southward of the line of the southern embankment. This entailed an application to Parliament and the necessary powers were conferred by the Board's Various Powers Act of 1921. The additional land taken in to the reservoir on the southern side was about 89 acres, including a portion of the village of Littleton. The alteration of the western embankment rendered the second baffle bank unnecessary.

Cottages and farm buildings had to be demolished and the Board built twelve cottages to take their place. The cost of the land and building work absorbed the greater part of an estimate of £50,000 approved in January, 1922. Arrangements were also made for the West Surrey Water Company to afford a temporary supply to the village of Littleton on account of the depletion of the local wells occasioned by the works.

Difficulties were encountered in administering the contract and in October, 1922, the Board approved modifications of certain terms which were subsequently included in a new agreement between the contractors and the Board. As a result of reviewing the financial position the Board, in November, 1923, approved a supplementary estimate of £400,000.

S. Pearson & Son, Ltd., finished their contract on 31st December, 1924. The work on the contractors' side was directed by Sir Frederick Hopkinson who, in June, 1925, completed the Sennar Dam in the Sudan for the same firm.

On 19th March, 1924, Mr. R. W. James (Chairman of the Works and Stores Committee) laid the foundation stone of the pumping station housing the machinery for lifting raw water from the intake channel at Laleham into the reservoir. The building was erected by John Laing & Co., Ltd., and the pumping plant, consisting of four single cylinder "uniflow" type steam engines driving large centrifugal pumps was made by Worthington Simpson, Ltd. The pumping capacity of each of these engines was seventy-five million gallons a day.

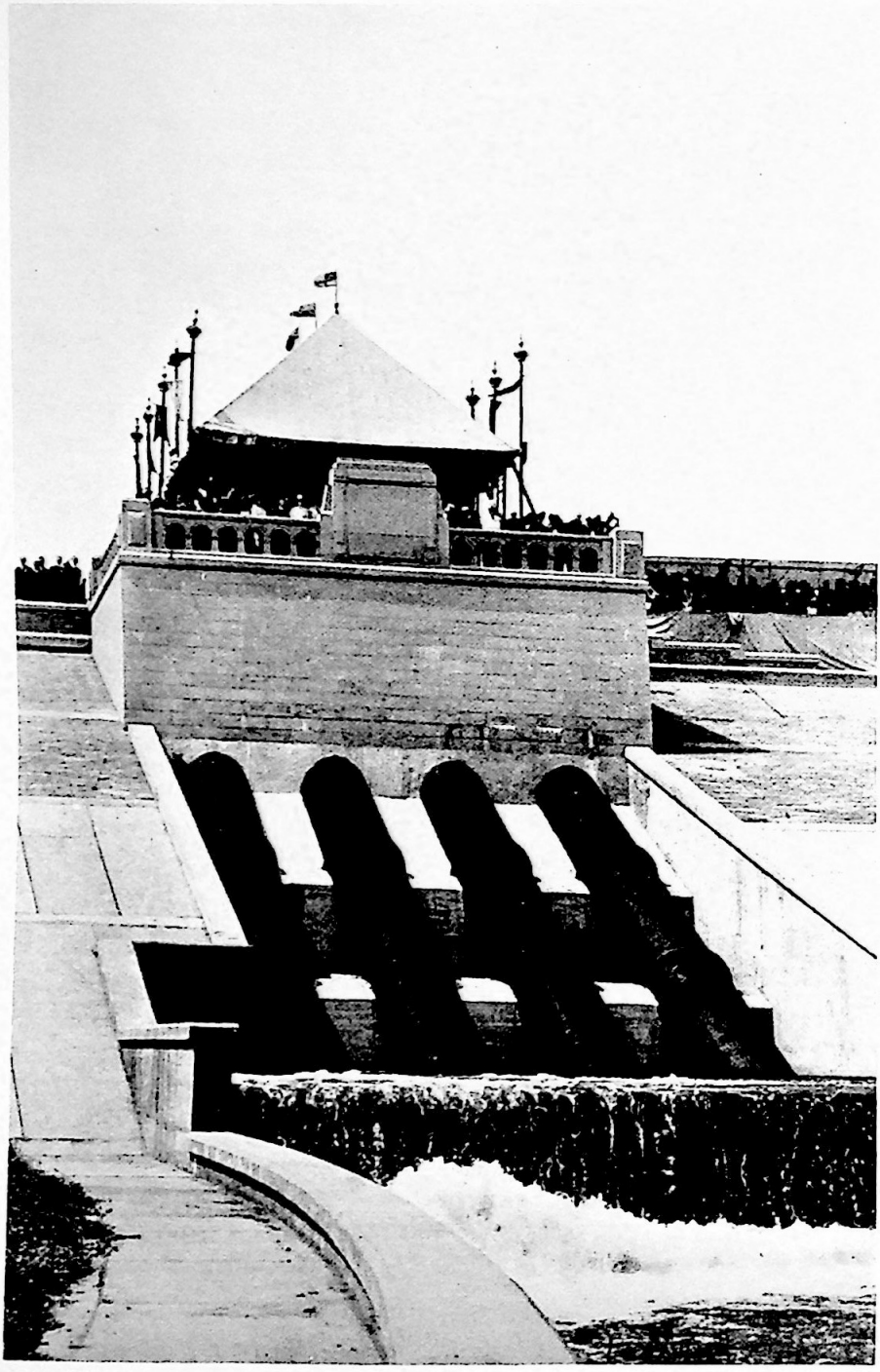
The reservoir was inaugurated on 13th June, 1925, by His Majesty King George the Fifth accompanied by Her Majesty Queen Mary. His Majesty performed the ceremony by putting the pumps into operation by electric signal and, having admitted the water, named it "The Queen Mary Reservoir."

With a top water area of 707 acres and a capacity of about 6,700 million gallons, this reservoir is the largest in the Board's possession and is believed to be the largest of its kind in the world.

The length of the enclosing embankment is nearly four miles and the City of London could be easily accommodated inside it with a moat all round. The maximum depth of the water is 38 feet and the height from the bottom of the reservoir to the top of the bank is 44 feet.

A very large quantity of London clay was required for the

THEIR MAJESTIES KING GEORGE V AND QUEEN MARY
AT LITTLETON RESERVOIR, 1925



WATER ENTERING THE QUEEN MARY RESERVOIR AT THE INAUGURAL CEREMONY

core wall and as all the material required for construction was taken from the interior of the reservoir, extensive excavation into the clay stratum was necessary, in places to a depth of between 30 and 40 feet. This clay was quarried at certain points by mechanical excavators and accumulated in large dumps for weathering purposes before being passed through pugging mills to make it suitable for the formation of the core wall. During this disintegrating process many fossils in the clay were revealed. Other deposits of archæological interest were also unearthed during the construction and certain of them were sent to the London Museum.

The construction of the reservoir naturally entailed the employment of a large number of men and a great amount of plant and materials. There were at one time 2,000 workmen engaged and two temporary power houses containing plant of 610 total horse power. There were also overhead electric power lines with connections to the pug mills and to the electrically-driven pumps, over 20 of which were used in dewatering the overlying gravel beds and keeping the trenches dry. Upon the works also there were about 32 miles of railway track, 20 locomotives, 500 waggons and trucks, two Lubecker excavators having an output of 2,500 cubic yards daily, and a variety of other machinery.

The total expenditure incurred amounted to £2,083,555. Resale of plant realised £94,380, which resulted in a net expenditure by the Board of £1,989,175.

Water was first drawn from the reservoir on 7th July, 1927.

The continuous duty of the pumping station has been such that the original boiler plant has proved insufficient. An electric motor was, therefore, installed in 1951 to replace one of the "Uniflow" engines. This motor, of 775 h.p., is the most powerful electric motor so far employed by the Board.

Distribution from the Queen Mary reservoir

It is necessary at this point to describe the arrangements for distributing the water from the Littleton reservoirs which later became the Queen Mary reservoir.

The Future Supplies report of May, 1912 (see p. 108), envisaged the construction of 15 acres of filter beds, in the first instance, at Kempton Park for treating the water conveyed *via*

the Staines aqueduct from these reservoirs and the proposed reservoir (No. 5) at Stanwell. The water filtered at Kempton Park was to be pumped to Shoot-up-Hill reservoir through a 57-inch main, 15 miles long, laid alongside the 42-inch Kempton Park–Fortis Green main as far as Cricklewood. This main would be connected at Greenford to a proposed service reservoir on Horsenden Hill. This arrangement avoided the necessity of acquiring lands for constructing filtration works at Stanwell and for laying a main from there to Horsenden Hill, which had been authorised by the Board's New Works Act of 1911. By delivering water into the Horsenden Hill service reservoir the greater part of the Western district was to receive higher pressure, a great advantage in view of the height to which large business premises, hotels, etc., were then being erected.

In July, 1912, it was decided to provide a second channel, in addition to the Staines aqueduct, so that alternative ways of conveying the water from the reservoirs at Staines and Littleton to the Kempton Park works would be available. Opportunities would then be afforded for manipulating the supplies drawn from these reservoirs, especially if algal or other difficulties should be experienced.

A Parliamentary Bill was therefore prepared empowering the Board to construct the proposed filtration works at Kempton Park, a steel conduit from reservoirs Nos. 6 and 7 to these works and a main to branch off to Horsenden Hill reservoir from the proposed 57-inch main at Greenford. It also provided for the duplication of the Kempton Park to Fortis Green main as far as Cricklewood. The Bill received the Royal Assent in 1913.

Construction of the first instalment of the Kempton Park filter beds was authorised by the Board in November, 1913, and in June, 1914, an estimate was approved for the Littleton–Kempton Park conduit, the new pumping station at Kempton Park, the Kempton Park–Horsenden Hill main (increased to 66 inches diameter) and the Horsenden Hill reservoir.

Mr. Bryan's proposals for the machinery at Kempton Park are not without interest. In 1905, on his recommendation, the Board's first steam turbine was installed at Old Ford well, mainly for experimental purposes, and in 1907 a second turbine

was erected at the Ferry Lane works, for pumping 10 million gallons a day of river Lee water into the New River at Stoke Newington. He now recommended that the new machinery should consist of three steam turbines, each capable of pumping 15 million gallons a day to Horsenden Hill, one being a standby and space being left for two further engines.

Kempton Park was to be an electric power station with three turbine-driven generators, two of which would be capable of transmitting energy through cables laid along the Staines aqueduct to the southern end of the dividing bank of the Littleton reservoirs. At this point there would be a station consisting of six "practically noiseless" electrically-driven centrifugal pumps, each capable of lifting between 40 and 50 million gallons a day into the reservoirs. Other cables would be connected to electric pumps at the Board's works at Sunbury and Hanworth Road and to an electric pump close to the Staines aqueduct to pump out of the reservoirs the water which was below gravitation level. One of the reasons for this electrification was that the nearest railway stations to Littleton (Shepperton and Ashford) were some distance away so that the cost of carting coal from either of these places would be considerable.

The works for distributing the water from Littleton were not put in hand during the first world war and Mr. Restler recommended certain important modifications. In 1915, he proposed the abandonment of the intended Horsenden Hill reservoir, and the extension of the proposed main from Kempton Park beyond Cricklewood to a point near Hampstead, where a 55 million gallon reservoir would be constructed with a top water level of 280 feet O.D. (the Horsenden Hill reservoir would have had a capacity of 20 million gallons and a top water level of 271 feet O.D.). The general effect of these proposals was to increase further the pressure in the distribution system served by the trunk main which would now include part of the Northern district.

Mr. Restler also suggested the substitution of vertical triple expansion engines for turbines and the retention of steam turbines as standby. He relied on the greater economic efficiency of the triple expansion engine at that time to reduce working expenses and result in an eventual overall saving on an entire plant of the turbine type.

For the purpose of equalising the period of storage in the Thames valley reservoirs (insisted upon by the Water Examination Committee), he proposed passing 19 million gallons a day from Littleton to proposed filtration works at Walton *via* Hampton. (See p. 126.) This would increase the amount of water passing through Littleton while decreasing the amount passing through the Molesey reservoirs. It was a costly business however and after the success of Dr. Houston's experiments in chlorinating the Staines aqueduct (see p. 255), which he considered would render equalisation unnecessary, Mr. Restler reported in 1917 in favour of abandoning this proposal.

He advocated the alteration of the line of the Littleton–Kempton Park conduit, which was originally intended to lie alongside the Staines aqueduct, so as to avoid constructional difficulties and risks of accident to the aqueduct during the construction of the conduit. At the same time he proposed that this conduit should be extended beyond Kempton Park to Hampton and that as far as Kempton Park it should consist of two lines of pipe each conveying half the total quantity, which would allow mussel growths to be cleared without throwing the conduit out of use.

Mr. Restler pointed out in his 1917 report that should chlorination be adopted it might be found possible to modify the Board's practice and use some form of high pressure filter for future installations.

With the war still going on, and work on the Littleton reservoir suspended indefinitely, the Board were at that time in no position to carry out these recommendations. When the armistice came they were without a Chief Engineer and when Mr. Stilgoe was appointed in January, 1919, he had to familiarise himself with the Board's works before he was able to advise the Board on the important questions involved. At the same time his services were very much in demand in connection with the Monro Inquiry. His report re-examining the whole question of distribution from the reservoir therefore was not presented until October, 1920. In this report Mr. Stilgoe estimated that Littleton reservoir would afford during a week of maximum demand an average daily supply of 134 million gallons. Of this, 49 million gallons would be discharged into the

existing Staines aqueduct and be passed on to Hampton and 85 million gallons into the previously proposed conduit to Kempton Park. After filtration at Kempton Park about 45 million gallons would be supplied to the Northern and Western districts by the main to be laid alongside the Kempton Park–Fortis Green main. Of this 45 million gallons a day, 8 million gallons would be supplied to the Ealing reservoirs, 17 million gallons to the centre of the Western district and 20 million gallons to the Northern district.

Confirming his predecessor's advice he recommended that the Littleton–Kempton Park conduit should be constructed on a revised line and in duplicate, each limb to be 72 inches in diameter; that the Horsenden Hill reservoir should be abandoned; that a service reservoir should be constructed at Hampstead, but of 45 million gallons capacity; and that vertical triple expansion engines with turbines should be erected at Kempton Park. It was also proposed that the filtration plant at this station should have a capacity of 21 million gallons a day, but as the questions relating to the comparative efficiency of high pressure as against slow sand filters or of rapid filtration followed by slow sand filtration had not yet been resolved, he did not consider it advisable to construct any new filtration works until a decision could be reached as to their relative merits.

Power to construct the Hampstead reservoir, now known as Bishop's Wood reservoir, and the extension of the main from Cricklewood to Fortis Green were included in the Board's 1921 Various Powers Act.

Construction of the Littleton–Kempton Park conduit was authorised by the Board in January, 1922. Although designed in twin form the Chief Engineer recommended that it would be a sound financial proposition to defer construction of the second limb until it was actually required. As the result of advertisement, tenders for its construction were received early in 1923, the lowest of which was accepted.

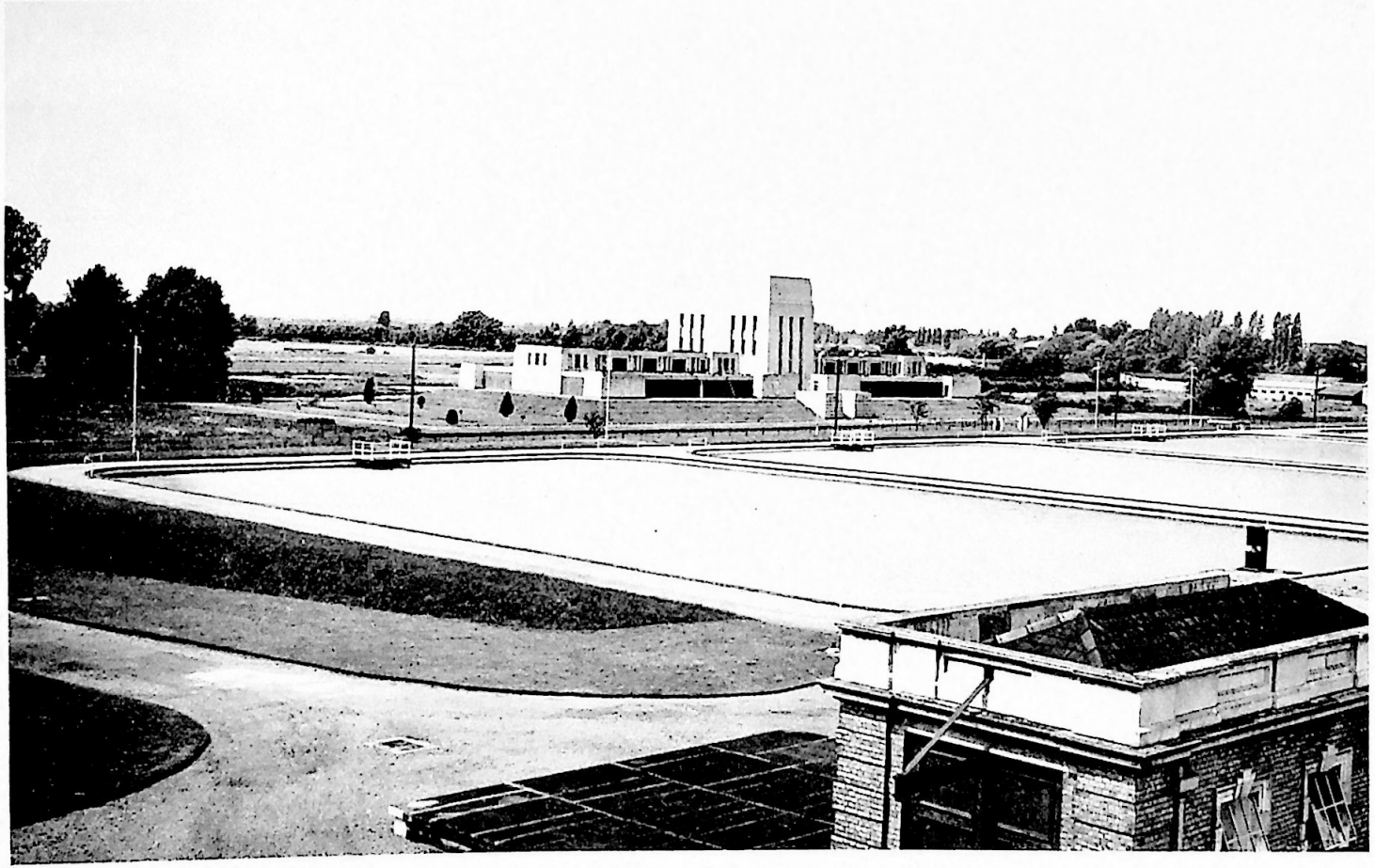
The execution of the contract was delayed and the Board eventually decided to terminate it. As from November, 1924, the work was carried out by the Board's own staff and was finished on 30th January, 1926. The conduit is two miles long to Kempton Park and six feet in diameter. From Kempton Park

it continues to Hampton as a 48-inch cast iron main. The construction of the second limb was proposed in 1936 but was not carried out. Instead, an 8-foot tunnel, connecting the Queen Mary reservoir outlet to the Ashford Common works, was authorised in 1947 (see page 142).

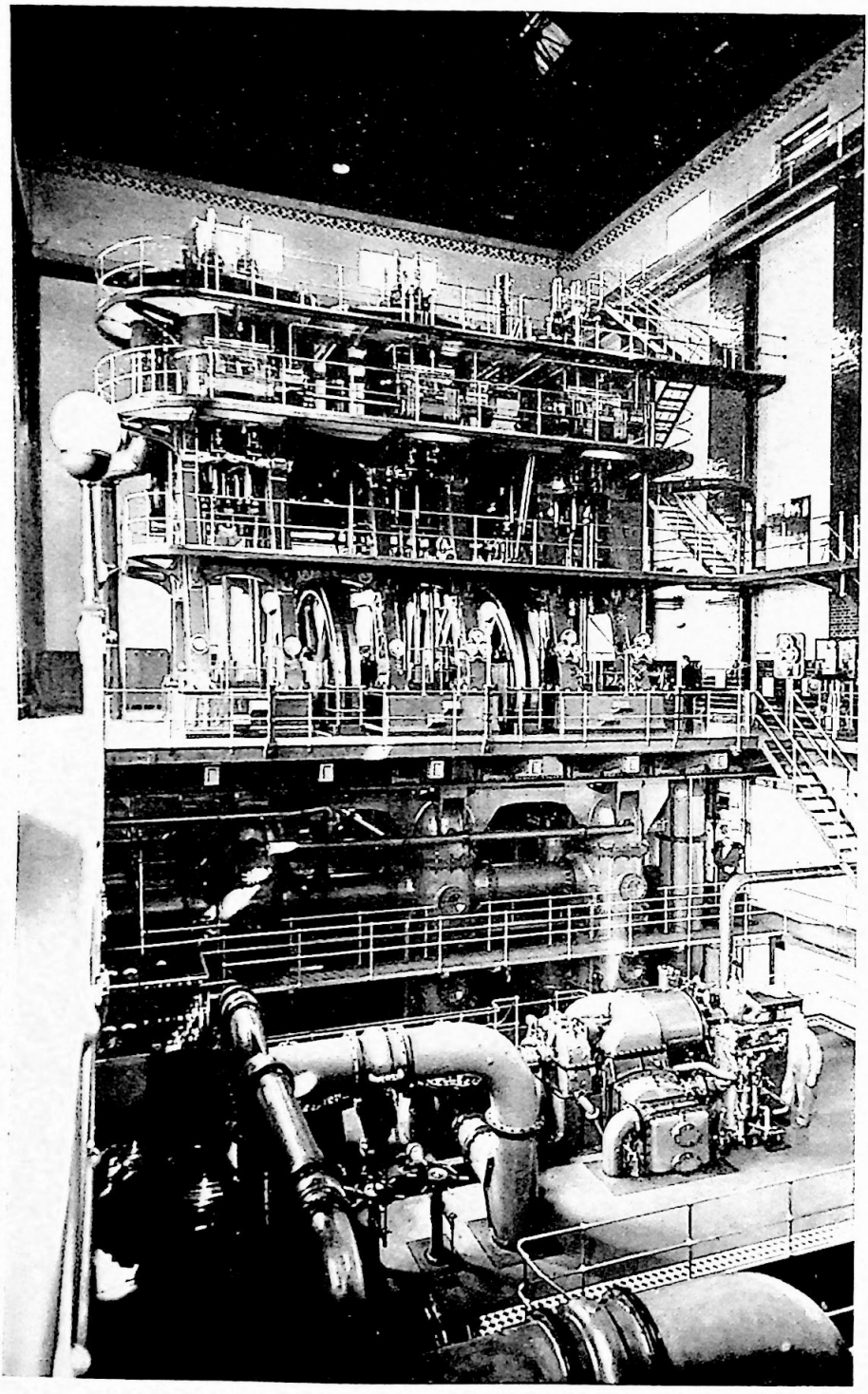
After being deferred for over a year on grounds of economy, consideration was given by the Board to other parts of the distribution scheme in February, 1923. The 42-inch Kempton Park-Cricklewood main which had been laid some 20 years before was still without any standby. Although 20 years is not a long time in the life of a main it was nevertheless most important that there should be some other means of communication as this main alone supplied the whole of the water to part of the Northern district and, in a smaller degree, to the higher zone of the Western district. As to engine power the very narrow margin that then existed for pumping filtered water had created difficulties recently when one of the "Riverdale" engines broke down. The three "Riverdale" engines at Hampton, each pumping nine million gallons a day, had been erected 25 years before but were still looked upon as the Board's latest engines for pumping large volumes of filtered water into supply.

At this meeting the following detailed scheme was examined : (1) the construction of the Bishop's Wood reservoir and extensions to the Fortis Green reservoirs, the latter work to be completed at a later date ; (2) the laying of the main from Kempton Park to Bishop's Wood as far as Cricklewood and mains branching eastwards—this main would not only assist the 42-inch main, but if connected thereto could postpone for a while the construction of the Bishop's Wood reservoir, as the Fortis Green reservoirs could for pumping purposes act as a "jack head" (i.e., the highest point to which water is pumped) ; (3) the erection of two large pumping engines at Kempton Park in a new engine house ; and (4) rapid filters to work in connection with the slow sand filter beds at Kempton Park. The new engines would, apart from pumping water through the new main, relieve the engines at Hampton and act as standby to those engines as well as to those at Kempton Park and Cricklewood. Items (2) to (4) were finally authorised.

The Board were informed that if the scheme were approved



FILTRATION WORKS, KEMPTON PARK
The Primary Filter House is shown in the background



TRIPLE EXPANSION ENGINE, KEMPTON PARK

Steam Turbine in foreground

it would be 2½ to 3 years before the engines at Kempton Park could be set to work and that therefore no further delay should take place. The Works and Stores Committee remarked on this occasion that although they were fully alive to the urgent necessity of reducing capital expenditure to a minimum, the Board were charged with a serious and responsible public duty and the failure to perform that duty would hardly be excused on the score of financial considerations. On 25th January, 1924, the Board accepted the tender of Worthington Simpson, Ltd., for the two triple expansion pumping engines for Kempton Park and that of the Paterson Engineering Company, Ltd., for the necessary apparatus for operating the rapid filters. In May and June of the same year the tenders of Sir W. G. Armstrong, Whitworth & Co., Ltd., for laying sections Nos. 1 and 2 of the 48-inch Kempton Park to Cricklewood main were also accepted. Section No. 1 was about 7½ miles long, extending from the works at Kempton Park to Windmill Lane, Greenford. Section No. 2 consisted of nearly five miles of 48-inch main, nearly a mile of 52-inch steel main from Windmill Lane to Cricklewood and over three-quarters of a mile of 27-inch main from Hanger Lane. The laying of the main was completed on 31st May, 1926. In May, 1925, the Board accepted the tender of William Moss & Sons, Ltd., for the construction of the engine house at Kempton Park and in May, 1927, their tender for the construction of the primary filters at that station.

The construction of the open rapid gravity primary filters, 24 in number, in reinforced concrete was proceeding satisfactorily and by March, 1929 the erection of the two triple expansion engines was nearly finished. Completion of the main building had been reported in January, 1929.

On 24th October, 1929, the works were inaugurated by the Minister of Health, the Right Hon. Arthur Greenwood, M.P., when the engines were named the "Sir William Prescott" and "Lady Bessie Prescott" engines, after the then Chairman of the Board and his wife. The engines are of 1,008 p.h.p. each and are of immense size, perhaps the largest in the world, the total height of engines and pumps being 62 feet. Each engine weighs 1,000 tons. They enable 24 million gallons to be pumped to the northern parts of London in one day. The primary filters

are each capable of dealing with 1½ to 2 million gallons of water per day, and thus have a total capacity of 48 million gallons per day. The system of primary filtration enables the secondary or slow sand beds to be worked at about four times their old rate. Without the adoption of this system it would have been necessary to construct a large number of secondary beds which would have occupied a considerable area of land.

In 1930, a small steam-driven pump was installed at the station to assist the old low lift engines in raising unfiltered water to the primary filters when a maximum demand coincided with a low level in the Queen Mary reservoir. In 1933, two steam turbines driving centrifugal pumps, each capable of pumping 12 million gallons a day of filtered water, were supplied by Worthington Simpson, Ltd., and placed in the new engine house to duplicate the triple expansion engines. This last installation finally disposed of the necessity of keeping the former East London Company's three Cornish engines at Hanworth Road station and they were formally closed down on 22nd March, 1934, by the then Chairman of the Works and Stores Committee, Sir George Handover. They were reconditioned for service during the last war, however, and were finally broken up in 1947–48.

Bishop's Wood reservoir

In May, 1927, the Board decided to go forward with the construction of the first instalment of the Bishop's Wood reservoir, Hornsey, authorised by the Metropolitan Water Board (Various Powers) Act, 1921, the 48-inch main from Cricklewood to Bishop's Wood (continued as a 42-inch from Bishop's Wood to Fortis Green), a 48-inch main from the above main to Bishop's Wood reservoir, and a 12-inch scour main from that reservoir.

It was intended to construct the Bishop's Wood reservoir in two sections. To construct the reservoir in one operation would have been less costly, but to be able to defer expenditure on the second section was of distinct financial advantage, outweighing any to be obtained by building the reservoir at one time. By building it in two sections the first was estimated to cost £125,000 instead of £105,000, but by so doing a further and immediate expenditure estimated at £85,000 was deferred.

When constructed, the new reservoir would act as a "jack head" for the supply from the Kempton Park works and would balance that afforded to the Northern and Western districts. In December, 1927, a contract was let for its construction and work started in January, 1928. During excavation for the foundations of the walls it was necessary to strengthen the south-east wall, and it was found to be more economical to omit the puddled clay backing and to render in cement the internal faces of the walls and floor. The reservoir was finished on 24th June, 1930, and brought into use on 15th December of that year. The capacity of the reservoir is 20¾ million gallons and the top water area is 4 acres.

In November, 1927, the Board accepted the tender of William Press & Son for laying the 48-inch and 42-inch cast iron mains from St. Michael's Road, Willesden, to the Fortis Green reservoir. These mains were also to prove useful in supplying additional high pressure water which was soon to be required in the Hendon area, then rapidly developing. That district was supplied from the Kidderpore reservoir and from the Cricklewood pumping station, but it would be possible to supply a portion direct from the Kempton Park–Bishop's Wood main, thus conserving the supply of high pressure water from the Kidderpore reservoir and the Cricklewood pumping station for the higher part of the district. The new main was to pass through rapidly developing districts and costs would therefore be saved by laying it at an early date. Completion of the contract was reported in February, 1930.

In April, 1929, the Board approved the laying of a new main 42 inches in diameter and 2¼ miles long, from Kempton Park to Hampton to connect the deliveries from the new pumps at Kempton Park with those from certain of the high lift pumps at Hampton. In the event of a serious breakdown to the Riverdale or Morelands engines at Hampton works, water could thus be passed from Kempton Park to Honor Oak or Nunhead reservoirs and likewise, in the event of a breakdown of pumps at Hampton supplying the western district, Kempton Park again could assist. Similarly the engines at Hampton could in case of necessity assist the district supplied from Kempton Park. A considerable length of the pipe was to be laid in water-bearing ballast and the remainder in clay, and

the Chief Engineer examined the relative suitability and value of steel and cast-iron pipes for this purpose. From a financial aspect the provision of cast-iron pipes was cheaper in that particular case whilst, owing to the nature of the soil and its water-logged condition where the main was intended to be laid, the physical conditions were such as to make the use of steel pipes most undesirable. The laying and jointing of this main was completed in November, 1930.

Walton and the Southern District

The last important work which had engaged Mr. Bryan's attention was the preparation of a scheme for the area south of the Thames, and a few days before his death he presented with Mr. Restler, then deputy chief engineer, a joint report on the subject. This report together with a subsequent one by Mr. Restler embodied the proposals now set forth.

The scheme was based on the opinion that an additional daily supply of 15 million gallons would be necessary to safeguard the supply south of the Thames. For this purpose it was decided to reduce the quantity of water afforded from Walton reservoirs to the Hampton works by 15 million gallons a day and in lieu thereof to supply Hampton with 15 million gallons a day from the Littleton reservoirs. This would be available from Littleton as it had been decided that the supply to Chelsea from the Thames at Surbiton should be retained.

At that time water was abstracted at Walton and was filtered partly at Surbiton and partly at Hampton, but in view of the proposed addition to the Southern district supply, the Engineers recommended the construction of filter beds at Walton, and the filtering there of a portion of the water abstracted so that it could be pumped directly into supply and thus avoid the delays and costs of intermediate pumping. This would be of still greater advantage to the Board in the event of an increased supply of Thames water being given to the lower levels of the Kent district.

The original plant at Walton was designed to deliver raw Thames water into the adjacent reservoirs and it was therefore necessary to erect new engines of a type suitable for pumping under high pressure at least 15 million gallons per day. The pumping mains between Walton, Surbiton and London were

then taxed at times to their utmost capacity so that it was also necessary to provide a new 42-inch main from the Walton pumping station to the reservoirs at Brixton and thence to the Beachcroft reservoir at Honor Oak. From Honor Oak a 30-inch main would have to be laid so as to make a connection with the existing 24-inch intercommunication main terminating at the Deptford works. The new main would be 15½ miles long as far as Brixton and four miles from Brixton to Honor Oak.

The Board adopted this scheme and gave instructions for a Bill to be prepared for submission to Parliament conferring the necessary powers. The Bill received the Royal Assent on 29th July, 1915.

The war delayed further developments, but Mr. Restler submitted an important report on the scheme in July, 1917, in which he recommended certain extensions. He considered that the filter beds at Surbiton for the supply to Chelsea were inadequate and suggested that four acres of beds at that station should be transferred to this supply and that an additional four acres should be constructed at Walton in their place. He also suggested the laying of a 48-inch in lieu of a 42-inch main from Walton to Honor Oak and the installation at Walton of a vertical triple expansion engine with a turbine as standby to pump the filtered water.

The Board endorsed these recommendations in January, 1919, and authorised the construction of the necessary works at a cost of £1,226,600. With regard to filtration, however, it was considered that the type of filter to be used would have to await the conclusions arrived at by the Chief Engineer and the Director of Water Examination after experiments on rapid filtration followed by chlorination had been carried out. The necessary plant for these experiments was in hand at the time and it was hoped to report on them shortly.

It was decided to divide the work of laying the 48-inch main from Walton to Honor Oak into three sections. The total length of the main would be 18½ miles. The first section extended from Walton to Coombe Road, Malden (7 miles), the second from that point to Thornton Road, Clapham Park (6⅔ miles) and the third to Honor Oak (4⅔ miles). The following contractors were engaged on the work:—John Mowlem & Co., Ltd., for section No. 1; Wilson Lovatt & Sons, Ltd., for

section No. 2; and the Consolidated Construction Co., Ltd., for section No. 3. The third and final section was completed in August, 1924, sections Nos. 1 and 2 having been completed in the previous April.

Hathorn Davey & Co., Ltd., built the large triple expansion engine with reciprocating pumps and Belliss & Morcom the steam turbine with centrifugal pumps. This installation was regarded as a first instalment to deal with 17,500,000 gallons per day and was considered to be sufficient for the requirements of the next 14 years. The large size would result in relatively low fuel and operating costs, while the consumption of coal per pump horse power was expected to be the lowest for any pumping engine so far erected in this country.

Contracts were entered into with the Paterson Engineering Co., Ltd., and the Candy Filter Co., Ltd., for the special plant required in connection with the installation of eight and ten primary filters in June, 1922, and on 27th July, 1923, the Board accepted the tender of Messrs. Christiani & Neilsen, a Danish firm, for the construction of 18 reinforced concrete primary rapid filters and six slow sand secondary filters. An assurance was given that all labour employed by the firm in connection with the contract would be British. The works were completed in 1926 and were inaugurated by the Minister of Health, the Right Hon. Neville Chamberlain, M.P., on Monday, 19th July, 1926.

Each of the 18 rapid gravity filters has an area of 416 square feet, as at Kempton Park, and is capable of filtering between one and two million gallons per day. The area of each of the six slow sand filters is five-sixths of an acre. The water is chlorinated after filtration.

As Walton was the first of the large works of the Board to adopt primary filtration it is of interest to record the saving that was effected by this installation. The total capital expenditure on the Walton filtration plant was nearly £183,000. The cost of the primary filters was approximately £46,000, and that of the slow sand or secondary beds, £127,000. A filtration plant to deal with 27 million gallons per day, a figure within the capacity of Walton, would, if equipped with slow sand filters only, have required not less than 18 acres of sand, costing,

on the basis of the Walton prices, £457,200. Thus a capital saving of £274,200 was effected.

Reference to new beds added in 1950 will be found at page 140.

CHAPTER XI

Future Supplies

1934–1946

THE experience of the 1934 drought (See p. 163), which was preceded by the dry summer of 1933 and very low flows in the Thames and Lee during the winter of 1933–34, convinced the Board that they were not in a secure position to afford a full supply and at the same time maintain the minimum statutory flow of 170 million gallons a day at Teddington under conditions prevailing in 1934. Accordingly, in October and November of that year schemes for increasing the storage capacity in the Thames and Lee valleys were placed before the Board.

For the Thames valley scheme a number of sites for reservoirs had been examined closely and at two of these, adjacent to existing reservoirs at Staines and Walton and conveniently situated in relation to existing intakes and pumping stations, clay was found at a favourable level. On each of these sites it was proposed to construct a reservoir of about 4,000 million gallons capacity. The depth of these reservoirs would be 50 feet as compared with the maximum of 40 feet in the Board's existing reservoirs. This extra depth would reduce the liability of the water to become algal and the inlets and outlets would be so arranged as to secure the maximum amount of circulation. The inner slopes would be covered with smooth slabs of concrete in preference to stone pitching or concrete blocks, the joints between which provide inaccessible breeding places for algae. Smooth slabs on the other hand can be brushed and scraped.

During 1933, the average daily quantity required from the Thames and its storage reservoirs was approximately 190 million gallons. The flow of the river in 1921 was lower than in any other year covered by modern gaugings and calculations based on a careful analysis of the daily flows in the Thames during that year showed that with the existing storage the

maximum quantity which could safely be drawn from the river under 1921 conditions was 167 million gallons a day. By constructing the proposed reservoirs the storage could be increased by a gross quantity of 7,870 million gallons, of which 7,500 million gallons would be available for supply. This addition would increase the total available reserve in the Thames valley from 13,000 million gallons to about 20,000 million gallons and the reliable yield from 167 million gallons a day to 213 million gallons. From these figures it was evident that until additional storage capacity was available it would not be possible to satisfy requirements under 1921 flow conditions. As the construction of the proposed reservoirs could not take less than four years it was considered advisable to seek Parliamentary sanction to reduce, during the construction period, the statutory minimum flow from 170 to 140 million gallons a day when there was vacant capacity in any of the storage reservoirs.

It was also proposed to lay further trunk mains on each side of the river. The main on the north side would deal with increasing demands in the Northern and Western districts. The extension of the Tube to Cockfosters was bringing a new population into the Northern district, whilst new factories along the Great West Road and at other points resulted in substantial additional demands for water for manufacturing purposes in the Western district where, too, large blocks of flats and offices were being substituted for ordinary buildings. The two mains to Fortis Green, 48 and 42 inches in diameter, lay side by side and supplied several branch mains running in an eastern and south-eastern direction. Since the 48-inch main was completed in 1930, considerable building had taken place in the districts through which the mains passed and only one additional main could be laid alongside these two. For this reason it was considered desirable to lay a 60-inch main in lieu of a second 48-inch main, which would waste space. This 60-inch main, however, would at present terminate at Cricklewood and might be continued at a later date to Fortis Green as a 48-inch main. The additional machinery required for pumping through the 60-inch main could be installed in the building housing the original pumping plant at Kempton Park which was now thirty-one years old, and which would be replaced by high

pressure steam turbines directly driving centrifugal pumps.

On the southern side of the river it was proposed to lay another 42-inch main, from Hampton to Honor Oak reservoir, which would meet the increased demand due to rapid building development in the Kent area.

Both the new northern and southern trunk mains were to be of steel, protected on the inside by a thick coating of bituminous composition applied centrifugally, and on the outside by a sheathing of similar preparation. Steel mains of large diameter were practically free from the risk of bursting to which pressure mains of cast iron were liable, and since the superior tensile strength of the metal enabled the thickness and weight of the pipes to be greatly reduced, pipes of greater length than those of cast iron could be used, thus reducing the number of joints and allowing more rapid laying. In the case of a 60-inch main, pipes up to 25 feet long could be used on straight portions, while this could be increased to 27 or 30 feet in the case of the 42-inch main. The bitumen lining also produces a smooth polished surface which permanently reduces friction losses.

These proposals for increasing resources were in the nature of an interim scheme. No attempt had been made in the short time at the disposal of Lieut.-Col. J. R. (later Sir Jonathan) Davidson, C.M.G., M.Sc., M.I.C.E., the Chief Engineer, to make a thorough investigation of the probable future needs of London or the extent to which the Thames could be further drawn on.

The total estimated cost of this scheme, including land, amounted to £4,083,000 made up as follows:—

Reservoir No. 1 (Staines)	£1,319,000
,, No. 2 (Walton)	1,317,000
Northern trunk main	927,000
Southern ,, ,, ...	520,000
	£4,083,000

The scheme was duly approved by the Board in October, 1934, and a draft bill granting the necessary powers was prepared for the ensuing session of Parliament.

Land in the Lee valley had been acquired for the construction of two reservoirs authorised by the East London Company's Act

of 1900 and one of these, King George's, at Chingford, was completed in 1913 (see p. 96). No further steps had been taken with the second one, however, apart from extending the time allowed by the Act of 1900 for its construction. The Board decided to construct this reservoir with the least possible delay in order to strengthen the position in east London. It would be situated immediately to the south of the King George's reservoir, with a water area of 334 acres. The depth of the water would be 36 feet at the north end and 41 feet at the south end, the gross capacity amounting to 3,180 million gallons. Owing to its location extensive works were required to deal with flood water carried by various streams crossing the site. The main channel would be an extension of the river Lee diversion, on the eastern side of the reservoir. This would require to be continued nearly $1\frac{1}{2}$ miles and would join up with an earlier diversion of the Lee. Flanders Weir, near the south end of the reservoir, would have to be replaced by new sluices and an overflow whereby water could be passed from the diversion into the supply channel or down the Lee. The reservoir was to be filled by a new pumping station of 100 million gallons a day capacity erected at the north-eastern corner. During winter months, when water for filling the reservoirs was most likely to be available, the plant at Chingford could assist by pumping through the King George's reservoir. The outlet works would be at the south end of the reservoir, connected with the recently completed 7-foot concrete conduit and with the supply channel so that water could flow either directly, or through the Walthamstow reservoirs, to Lee Bridge. The scheme was approved by the Board at their November meeting, when expenditure of £950,000 was authorised, of which £867,000 was for the reservoir itself.

The Board's Bill, granting powers to construct the Staines and Walton reservoirs in the Thames valley and extending the time for the construction of the reservoir in the Lee valley, received the Royal Assent in 1935.

In October, 1935, the Board approved an estimate of £1,239,000 for the reservoir at Staines and decided to wait until it was put in hand before starting on the Walton reservoir.

Steps were immediately taken, however, to buy the necessary land for this latter reservoir. The area required was 479 acres, the estimated cost of which was £182,500.

In July, 1937, the tender of John Mowlem & Co., Ltd., at £1,291,998, was accepted for the Staines reservoir. The date of commencement of the contract was August, 1937, the contract date of completion being February, 1941.

An estimate of £1,217,000 for the construction of the Walton reservoir was approved by the Board in April, 1938, although it was pointed out at the time that the estimate would probably be exceeded owing to rising prices. The estimate included additional pumping machinery at the Walton engine house and about $1\frac{3}{4}$ miles of large diameter conduit to be laid from the engine house to the inlet of the reservoir. The draw-off was to be connected to the filtration plants at Hampton, Walton and Surbiton. The tender of Sir Robert McAlpine & Sons Ltd. at £839,471 was accepted in October, 1938, and the date of commencement was February, 1939, the contract date for completion being January, 1943. With the outbreak of war, however, this contract was terminated in accordance with the provision of a war clause embodied in it. Steps were immediately taken to protect against injury from the weather so much of the works as had already been carried out and the contractors handed over the site to the Board. It has not yet been possible to obtain Government sanction for the resumption of the work.

Meanwhile rapid progress had been made with the Staines reservoir. As the contract allowed only $3\frac{1}{2}$ years for completion, which involved the excavation and placing of several million cubic yards of material, the contractors provided a large quantity of the latest earth-removing plant of American manufacture and it was decided to work continuously day and night. By April, 1939 practically all the puddle had been deposited in the cut-off trench and approximately thirty per cent. of puddle had been placed on the core wall. About 2 million cubic yards (approximately fifty per cent.) of the filling to the main embankment had also been deposited. By September, 1939, seventy three per cent. of the value of the contract had been completed although only fifty-eight per cent. of the contract time had elapsed. At this time the number of men employed was over

By courtesy of Studio Egham

HIS LATE MAJESTY KING GEORGE VI AND HER MAJESTY QUEEN ELIZABETH THE QUEEN MOTHER
AT THE NEW RESERVOIR, STAINES, 1947

HIS LATE MAJESTY KING GEORGE VI AND HER MAJESTY QUEEN ELIZABETH THE QUEEN MOTHER LEAVING THE OUTLET TOWER, STAINES, 1947

1,000, while the average during the period of just over two years had been 700.

With the outbreak of war, however, the whole rate of progress was greatly reduced. In spite of the cessation of night work on account of lighting restrictions and the exceptionally severe winter of 1939–40, the reservoir was three-quarters completed by April, 1940, and it was still hoped that it would be completed some time in 1941. The bulk of the heavy plant, however, had been requisitioned for urgent Government work and the labour force had quickly dropped to one half and steadily decreased until only 30 men were left in 1944. Not only was the labour force limited but it was also below normal efficiency. This became particularly noticeable in connection with the formation of the puddle core walls which involves arduous work. By April, 1944, all major works were completed with the exception of the concrete lining of which one-third had been finished.

On the cessation of hostilities some of the plant was recovered and by the end of 1945, as the result of representations to the Ministries of Health and Works for an adequate supply of labour, two hundred German prisoners of war were allocated to the work. They were chiefly employed on the concrete slabbing of the interior slope of the bank.

If little progress was possible during the war it is interesting to record that the site was the scene of considerable activity on work of national importance. It was here that the main experiments with mobile flame throwers were started in August, 1942, while towards the end of the same year the trials of apparatus for the dispersal of fog on airfields were also carried out. As the embankments were practically up to their full height, this work was under cover from ground observation and the site provided a suitable location for these tests which were continued up to the end of the war.

The reservoir was inaugurated on 7th November, 1947, by His late Majesty King George the Sixth accompanied by Her Majesty Queen Elizabeth the Queen Mother, and is named "The King George the Sixth Reservoir."

This reservoir, the Board's second largest in capacity, was constructed to the designs of Sir Jonathan Davidson, who first as Chief Engineer from 1934 to 1939 and later as Engineer for

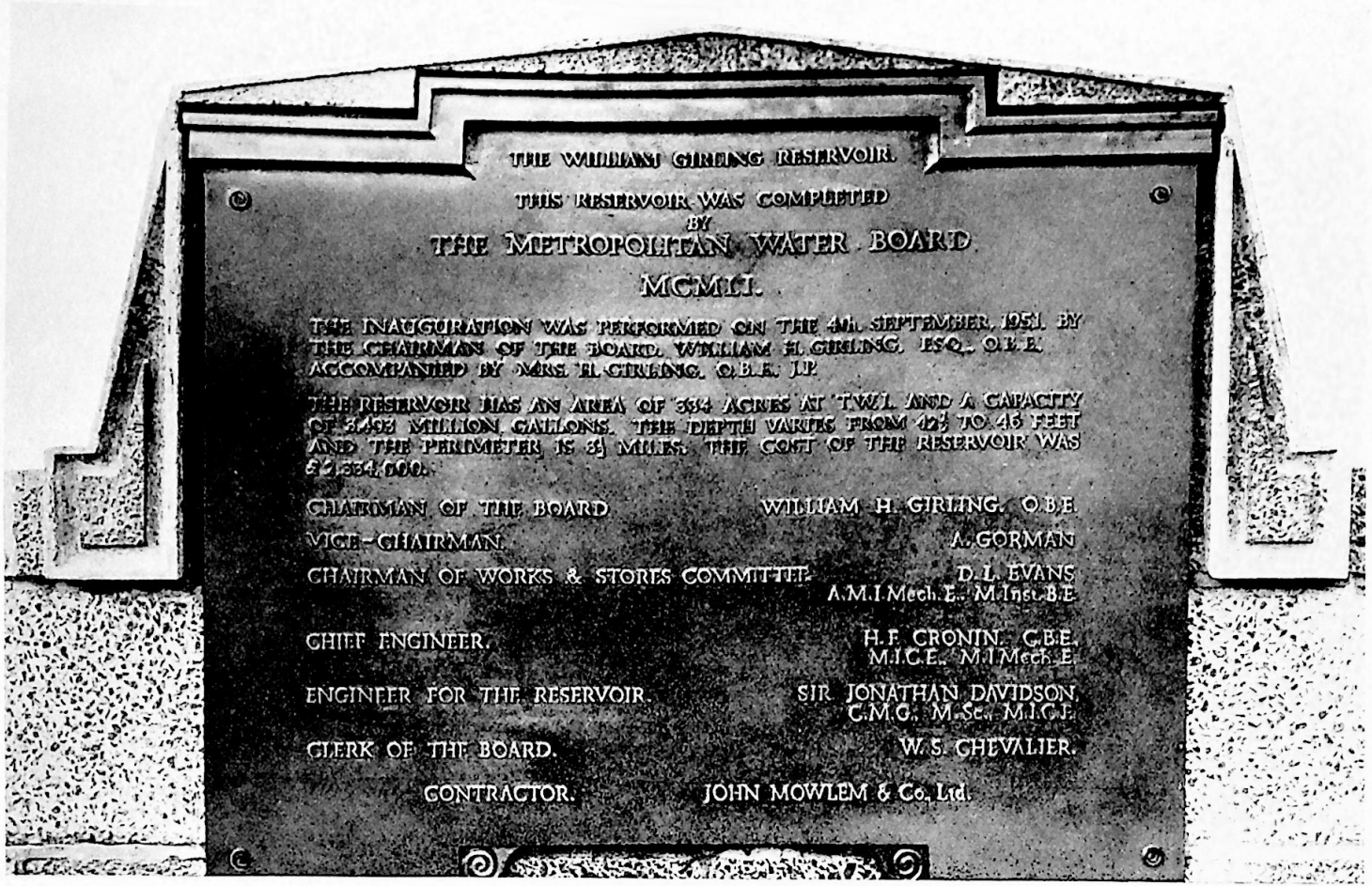
the construction of major works, had been responsible for all stages from inception to completion.

The capacity of the reservoir is 4,450 million gallons, which amounts to an increase in the gross capacity of water in reserve at Staines of 130 per cent. The length of the reservoir is over a mile while its width varies from 722 yards to 962 yards. The water surface covers 350 acres, an area approximately the same as that of Hyde Park, and the distance round the top of the bank exceeds $3\frac{1}{4}$ miles. The average depth is 52 feet while the height of the embankment above ground level at the south end of the reservoir is 54 feet.

It is now necessary to refer to the Lee valley reservoir. The tender of John Mowlem & Co., Ltd., of £682,156 for this was accepted by the Board in July, 1935. Delay in construction was experienced at first by flooding, but by the end of 1937 the river Lee diversion together with a relief channel and the intake channel were completed. A slip occurred in July of that year in the partly formed embankment at the north-west corner of the reservoir, where the bank had reached a height of 25 feet. The slip had been caused by the failure of the clay underlying the embankment to sustain its load. Whilst investigations were in progress a second movement occurred in the early part of December, 1937, near the first slip. This, although comparatively small, was due to the same cause.

In works of this magnitude and character the factor of safety is of first importance. It was essential to ensure stability beyond all doubts and this involved the consideration of highly technical questions. After exhaustive investigations and discussions with the contractors and consultations with two independent specialists in soil mechanics, Dr. Herbert Chatley and Professor Karl Terzaghi, the Board in July, 1938, approved a scheme which embodied important modifications of the original design. The principal alterations were (a) a considerable increase in volume of material in the bank; (b) the formation of ballast haunches resting on the natural ballast on each side of the bank with a flat ledge at a uniform level of 16 feet below the top of the bank; (c) a mixture of 40 per cent. ballast with the clay in the construction of the central portion of the bank between the ballast haunches. The reservoir had to

THE COMMEMORATION TABLET, QUEEN MARY RESERVOIR



THE COMMEMORATION TABLET, WILLIAM GIRLING RESERVOIR

be redesigned and its new shape increased the capacity by 362 million gallons, or 11.3 per cent.

The adoption of this modified design meant a considerable increase in the amount of work and time necessary for finishing the reservoir and costs were therefore substantially increased. A provisional supplemental estimate of £500,000 was approved in that connection.

The delay caused by the war in completing this reservoir was even more marked than in the case of that at Staines. By the end of the war the banks were still being raised but the outlet works had been completed. Work on raising the embankments and the placing of puddled clay to form the core wall continued during 1946. Early in 1947 the concreting of the inner slopes had begun, although the very bad weather experienced during the first three months of that year had slowed down work very considerably. A small allocation of prisoners of war was also made for work on this reservoir. An extension of time until 30th June, 1950, for completion was granted by Order and a further Order in 1950 extended the time to October, 1954.

Further supplemental estimates were approved on a number of occasions, bringing the total estimated cost of the reservoir to £2,334,000.

The reservoir was inaugurated by the Chairman of the Board, Mr. William H. Girling, O.B.E., on 4th September, 1951, and was named the "William Girling" reservoir. It has a capacity of 3,500 million gallons, a perimeter of $3\frac{1}{2}$ miles and a surface water area of 334 acres. It was designed by Sir Jonathan Davidson.

The trunk mains

In May, 1936, the Board approved expenditure of £520,000 for the proposed 42-inch main from Hampton to Honor Oak reservoir which was to have a length of 17 miles. The main was to be laid in three sections and in April, 1937, the tender of J. B. Edwards & Co. (Whyteleafe), Ltd., was accepted for laying section No. 2, which was about $5\frac{1}{4}$ miles long, extending from Beverley Brook, Wimbledon to Oakmead Road, Wandsworth. For laying section No. 1 which extended from Hampton to the Beverley Brook, a distance of nearly $6\frac{1}{2}$ miles, the tender of Nott, Brodie & Co. Ltd. was accepted in January, 1938.

Section No. 2 was finished in 1938, and in March, 1939, a contract was entered into with J. B. Edwards & Co. (Whyteleafe), Ltd., for laying section No. 3 from Oakmead Road to the Honor Oak reservoir, a distance of $5\frac{1}{4}$ miles. Section No. 1 was finished in 1940, and section No. 3 in 1942.

The laying of the 60-inch main from Kempton Park to Cricklewood, sanctioned by the 1935 Act, was deferred until after the war. In June and November, 1947, estimates totalling £1,500,000 were approved in this connection. It was decided that this $13\frac{1}{2}$ mile main should receive 47 million gallons a day from the proposed filtration works at Ashford Common (see page 142).

The main, laid in four sections, is practically completed. Double spigot steel pipes sheathed and lined with bitumen and jointed with Johnson couplings have been used. This joint consists of a steel collar surrounding the ends of the pipes to be joined, the joint itself being made by rubber rings and held in position by clips bolted across the collar. This was the first time that the method was proposed to the Board for a long distance main but it had been approved by the Ministry of Health and enquiries made from other authorities confirmed that results had been satisfactory.

The tender of J. B. Edwards & Co. (Whyteleafe), Ltd., was accepted in October, 1948, for laying section No. 1 (from Kempton Park to Wesley Avenue, Hounslow). This section was completed in September, 1951. The tender of the Cementation Co., Ltd., was accepted in July, 1949, for section No. 2 (Wesley Avenue, Hounslow, to Lyndhurst Avenue, Southall) and this was completed in July, 1952. J. L. Eve Construction Co. Ltd.'s tender was accepted, in March, 1950, for section No. 3 (Lyndhurst Avenue, Southall, to Abbey Avenue, Wembley). Completion of this section is expected shortly. For section No. 4 (Abbey Avenue, Wembley, to Cricklewood pumping station) the tender of J. B. Edwards & Co. (Whyteleafe), Ltd., was accepted in April, 1951. The work on this part is still in progress.

Wraysbury and Datchet reservoirs

As previously stated, the 1934 scheme was in the nature of an interim scheme (see p.132). In May, 1939, shortly before he

retired as Chief Engineer, Sir Jonathan Davidson submitted a report on Future Supplies in which he dealt with the probable future demands, assessed the yields of the various sources and set out the storage requirements in the Thames valley up to the year 1971. In the following year a special Future Supplies Committee was appointed. Their report, which took into consideration the above report and a supplementary one by Mr. H. F. Cronin, C.B.E., M.I.C.E., the present Chief Engineer, was submitted to the Board in June, 1944.

The Committee agreed with the findings of the two engineers that the only method of appreciably increasing the supply from existing sources was by the provision of additional reservoirs in the Thames valley. Storage capacity in the valley at that time remained at 13,892 million gallons. The reservoirs at Staines and Walton then under construction would, when completed, raise this to some 21,400 million gallons.

Owing to building developments and to the fact that the London clay became thinner and eventually petered out near Eton, sites for reservoirs in the lower part of the valley became increasingly difficult to obtain and in view of the probability of further developments taking place after the war this difficulty was likely to become more acute. Both the engineers recommended that sites for at least two additional reservoirs should therefore be acquired. Two such sites, with areas of 750 and 510 acres, were examined and tested at Wraysbury and Datchet.

In the absence of information as to the future development of London and Greater London, it was not possible at the time to give a reliable forecast of the extent of post-war demands based on population. Actual supply figures, however, showed that consumption had increased much more rapidly than population. A warning that the consumption was generally increasing was also contained in a White Paper on National Water Policy which had been issued in 1944 and which stated that:

> "As standards of living rise the consumption of water increases—and, apart from waste, rightly increases—by leaps and bounds. Indoor sanitation nearly doubles the consumption of water, and the greater use of baths, the provision of constant hot water, the washing of motor-cars, all add to the demand, as does the widespread and growing use of water in many industrial processes. . . ."

The reservoirs which could be constructed at Wraysbury and

Datchet could contain about 4,000 and 3,000 million gallons and a scheme was prepared entailing the construction of a new intake, a pumping station and conduits.

If these were constructed the Board would have a storage capacity of approximately 28,400 million gallons in the Thames valley and the safe supply which could be obtained with this capacity during a year when the flow was similar to that of 1899, would be 382 million gallons a day for the whole area or approximately 270 million gallons a day of Thames-derived water. With flows such as occurred in 1921 recourse would have to be made to the reduction of the statutory flow at Teddington Weir. (Fuller information on the Board's storage policy will be found at p. 165.)

It was not possible to forecast when the new reservoirs would be required, but the Special Committee considered that an undertaking of the Board's size should not only have an ample and safe margin, but should also look ahead of present requirements.

The Board approved the report and decided to include provisions authorising the acquisition of lands for these reservoirs in the Bill to be promoted in the ensuing session of Parliament. At their next meeting the Board agreed to acquire an additional 230 acres for the Datchet site and to aim at constructing reservoirs of 6,000 and 5,000 million gallons capacity. The necessary powers were subsequently embodied in a Bill introduced in the 1944–45 session of Parliament, and this Bill, after being delayed by the General Election of 1945, received the Royal Assent in April, 1946.

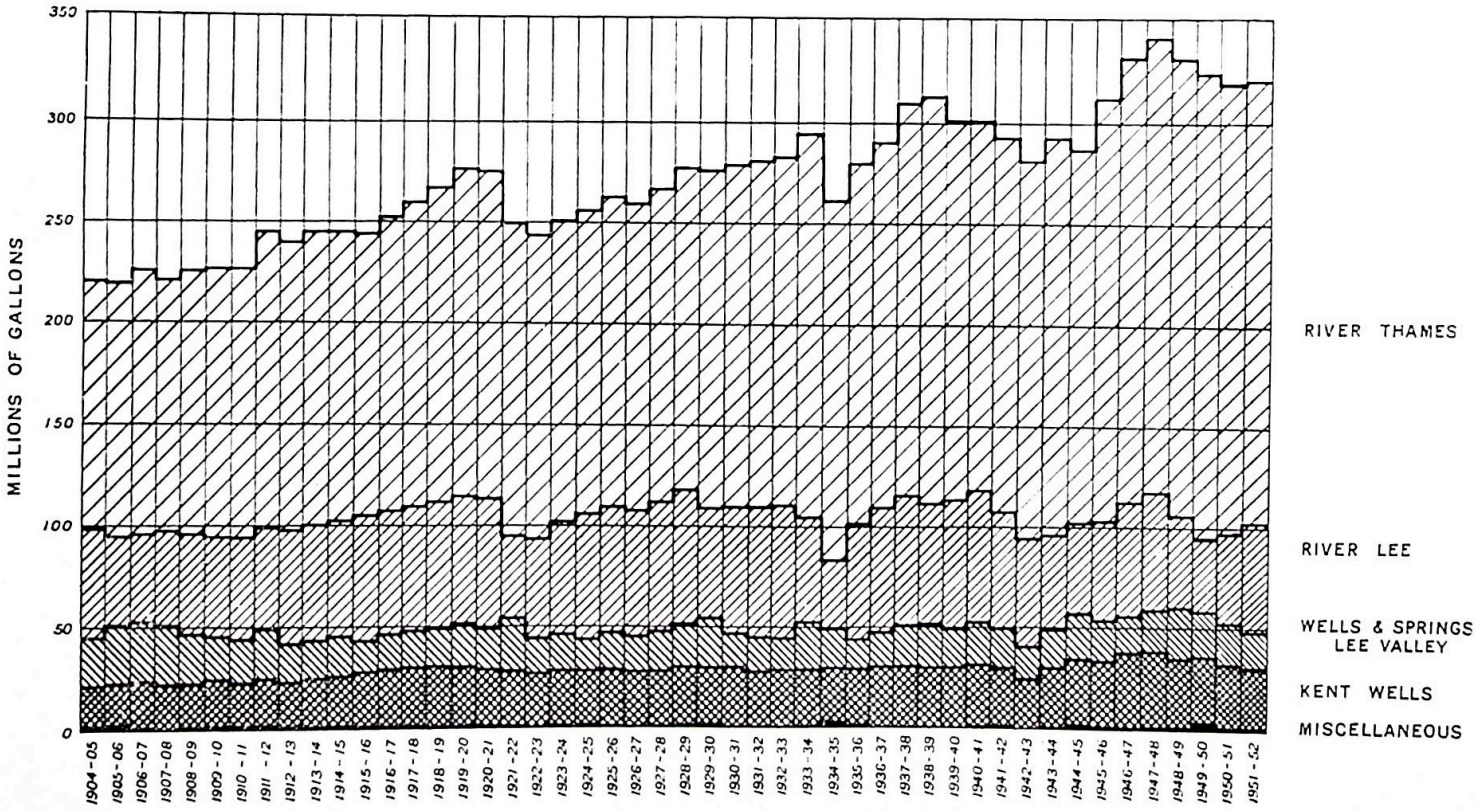
In December, 1946, the Board approved expenditure of £917,665 for the reservoir sites and other lands for works sanctioned by the Act, and the land for the reservoirs has since been bought. No further steps have been taken, however, towards their construction owing to the economic situation and the shortage of labour.

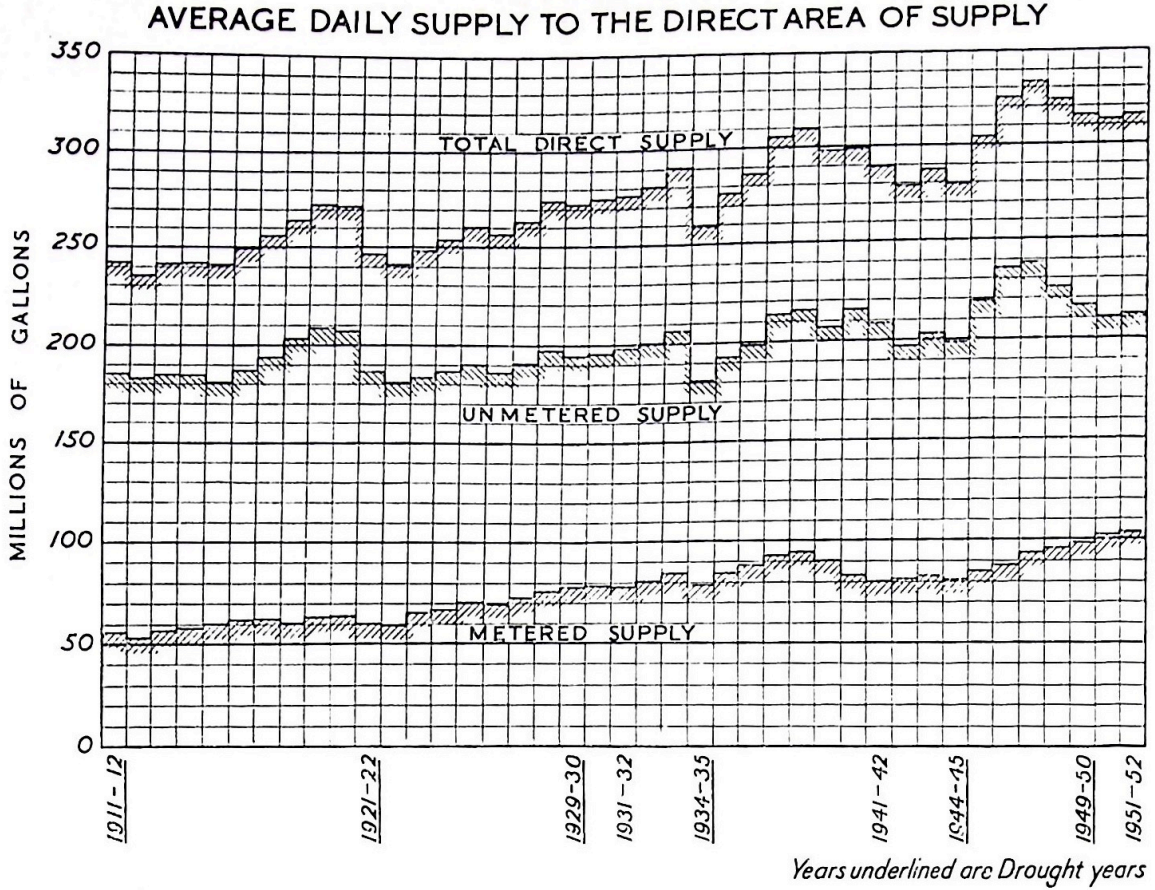
Filtration works.—(a) Walton

In June, 1944, the Board not only decided to seek statutory powers for acquiring land for the reservoirs at Datchet and Wraysbury, but also sought to acquire land for filtration works at Kempton Park, Walton and Ashford Common. The necessary

METROPOLITAN WATER BOARD

AVERAGE DAILY SUPPLY (INCLUDING BULK) FROM ALL SOURCES





METERED AND UNMETERED SUPPLIES, 1911-12 TO 1951-52

powers were embodied in the Board's 1946 Act. The total increased filtration capacity from these additional works was calculated at 190 million gallons a day which, when added to 240 millions, the capacity of the filtration works it was proposed to retain, gave a total of 430 million gallons, which might eventually have to be provided in the Thames valley to maintain a daily average supply of 300 million gallons.

At Walton it had been decided to acquire 40 acres of land to increase the capacity of the station eventually to 60 million gallons a day. In November, 1946, it was decided to construct four filter beds at that station to reduce the rate of filtration which was too high and to raise the daily output to 30 million gallons. The tender of John Mowlem & Co., Ltd., was accepted for the work in July, 1947, and this was started in the following October. In June, 1950, the beds were inaugurated by the Chairman of the Board, Mr. William H. Girling, O.B.E. The beds, which were constructed to the designs of the Chief Engineer, embody certain features calculated to safeguard the purity of the water.

(*b*) *Ashford Common works*

When filtration works at Ashford Common were considered by the Board in 1944 it was proposed that their filtered water capacity should amount to 55 million gallons a day. In June, 1947, however, it was decided to increase the capacity to 90 million gallons. In arriving at this decision the Board were influenced by the following considerations.

From the year 1906–07 to the year 1946–47 the average daily supply had risen from 225 to 332 million gallons, and at that time there was no sign that stability had been reached. The indications were, in fact, that the supply for the year 1947–48 would average 350 million gallons a day and that the demand would increase in future years. In calculating the capacity of filtration works the plant must be designed to yield the quantity required on a series of days of maximum demand. From the records of pre-war years it could be assumed that the supply on the maximum day would be about 130 per cent. of the annual average, so that with an average of 350 million gallons a day, a peak demand of 455 million gallons could be expected during the summer.

In 1947, the Board's filtration works were able to deal with 315 million gallons, and this, with 45 million gallons obtainable from wells, gave a total supply of 360 million gallons a day, thus leaving a deficiency of 95 million gallons on a day of maximum demand. At times the supply had exceeded this figure, but it had only been possible to do so during periods of exceptionally favourable conditions or by overworking the filtration plant which resulted in the more frequent reconditioning of filters. On Monday, 2nd June, 1947, the supply reached the record figure of 428 million gallons. The supply failed in certain areas and tank waggons began to make their appearance on the streets. This was followed on the succeeding day by a total supply of 422 million gallons. These figures were over 60 million gallons in excess of the normal capacity of the works.

The filter beds which had recently been authorised at Walton and the reconditioning of the filter beds at Hampton which the Board had approved in January, 1947, were designed to yield an additional 26 million gallons by 1950. If, therefore, the supply on a maximum day in that year should rise to no more than 455 million gallons there would still be a deficiency of 69 million gallons in the total capacity of the filtration plant and wells.

The filtration capacity previously contemplated for the works at Ashford Common, namely, 55 million gallons a day, would still leave a deficiency of 14 million gallons out of the 69 million gallons deficiency already referred to. The site was sufficiently large, moreover, to house the plant designed for an output of 90 million gallons a day.

Water for these filtration works would be obtained from Queen Mary reservoir by means of an 8-foot tunnel from the reservoir outlet, and arrangements would also be made to take water from the 72-inch Littleton–Kempton Park conduit, the Staines aqueduct, and the proposed Wraysbury and Datchet reservoirs.

The filtration plant would consist in the first place of aeration basins where the water would be cascaded when necessary, to increase its oxygen content.

From the aeration basins the water would pass through a battery of micro-screens, instead of primary filters. Experiments in passing stored water through rotating screens with a fine mesh had been carried out at Surbiton works during the war.

This mesh was able to entrap the algae and other larger impurities in the water and thus perform the same function as a primary filter.

The results obtained when working the screens in conjunction with slow sand beds showed that the plant was able to reduce the algal content of the water to much the same extent as a primary filter. Unlike primary filters, however, they do not improve the chemical quality of the water so that reliance must be placed on the slow sand beds for chemical purification. The cost of installing such screens would be less, however, than the cost of primary filtration plant of the same capacity, and the loss of head would be smaller.

From the micro-screens the water would pass to 32 slow sand beds. These would be raised above the ground level to prevent possible contamination from ground water. The water would then pass through contact tanks of sufficient capacity to balance variations in pumping load.

Various types of drive for the low lift pumps, to convey raw water from the Queen Mary reservoir and the Staines aqueduct, and high lift pumps, for pumping into supply, were considered. It was finally decided that both from financial considerations and from an amenities standpoint, the station should be driven by purchased electricity operating motors at 3,300 volts, with diesel alternators for load relieving purposes and gas turbine alternators, to form, with the diesel alternators, a complete standby in case of failure of the grid. This would be the first occasion on which the gas turbine would be employed by the Board.

The filtered water would be distributed through three mains, two of 48 inches diameter and one of 54 inches diameter, but it was not proposed to proceed with one of the 48-inch mains at that time. The 48-inch main and the 54-inch main would both be laid in steel with welded joints. The 48-inch main would convey filtered water to Hammersmith *via* Barnes, when the filtration plant at the latter station was abandoned, and in the meantime would supplement the supply from Hampton. The 54-inch main would be used to feed the proposed 60-inch main from Kempton Park to Cricklewood and thus reinforce the supply from that station.

The estimate for these works, approved by the Board, amounted to £4,290,000.

In order to speed up the work the Board, in August, 1947, decided to enter into a contract with John Mowlem & Co., Ltd., who were then finishing the King George VI reservoir and had a depot available at Staines, for the whole of the building, civil engineering and constructional work at Ashford Common on a cost-plus-fee basis.

On account of the high cost of mainlaying and the increased cost of materials which subsequently occurred, the Board in February, 1949, authorised further expenditure of £196,800. Tenders were invited in March, 1949, from selected contractors for the three gas turbine units. As was to be expected in a new development the machines offered by the various makers differed considerably. It was difficult at that stage to ascertain their relative merits but in order to obtain as wide an experience as possible of this type of plant, the tenders of the following firms were accepted for one unit each, namely, the Brush Electrical Engineering Co., Ltd., the English Electric Company, Ltd., and Metropolitan-Vickers Electrical Co., Ltd.

At a later date the Board approved the acceptance of the tender of Vickers-Armstrongs, Ltd., for eleven low lift pumps.

The tender of Kinnear, Moodie & Co., Ltd., was accepted in October, 1951, for the tunnel connecting the outlet of the Queen Mary reservoir to the works.

In June, 1951, the Board authorised the provision of a travelling sand-handling bridge to span the filter beds on the eastern half of the works and to operate in conjunction with a central sand-washing plant.

Satisfactory experiments were subsequently conducted with a machine designed to clean sand efficiently without removing it from the filter bed. The adoption of this method would effect considerable economy because it would no longer be necessary to remove the dirty sand from the filters and transport it to the washers, or to store clean sand for replacement on the filters. The filter beds would not have to be emptied before cleaning nor re-charged with water after cleaning. Another advantage was that the sand would no longer be exposed and therefore would not be subject to possible pollution. Hydraulic filter bed sand-washing plant supported on a travelling bridge was

therefore designed and it is now intended to instal this plant to serve the remaining sixteen filter beds on the west half of Ashford Common works. The travelling bridge, which will be mounted on rails on the filter walls, will span the filter beds, and is designed to travel on rails between the filter beds so that it will operate on all sixteen beds.

The 32 slow sand filters, the aeration basins and the tunnel from Queen Mary reservoir have been completed, and considerable progress has been achieved in the construction of the two contact tanks and the laying of the necessary mains. Good progress has also been made with the construction of the engine houses, of which the main roofs have been concreted and asphalted, and the internal floors laid. Foundation blocks for the machinery are in course of construction and the high lift pumps are being installed.

CHAPTER XII

Future Supplies

1946–1953

Enborne

DURING the years immediately following the war, the demand for water reached unprecedented levels, as the following figures for the years 1937–38 to 1947–48 will show:

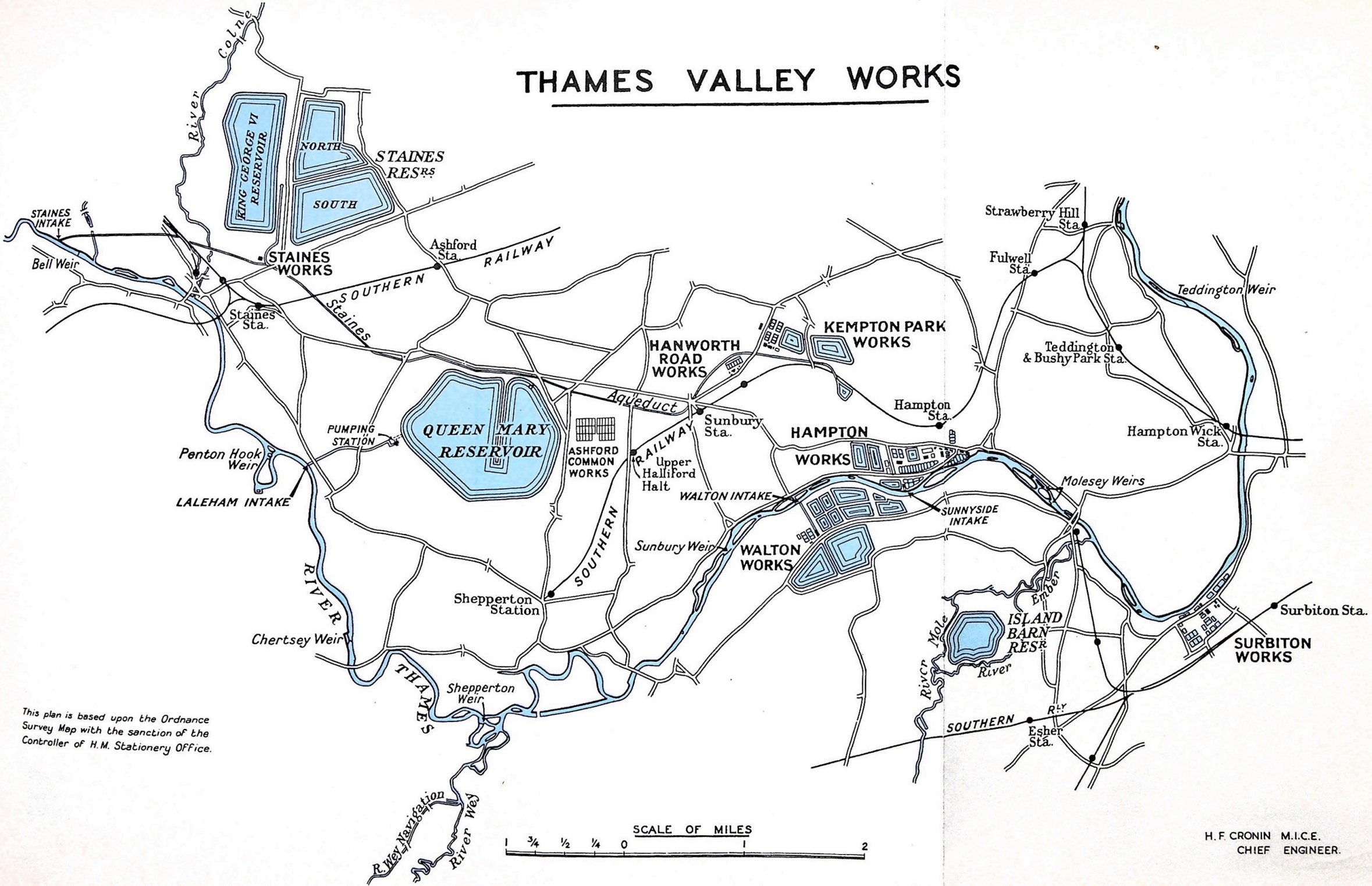
Year.	Total daily average supply (including bulk supplies).	Year.	Total daily average supply (including bulk supplies).
	million gallons.		million gallons.
1937–38	309.2	1943–44	293.4
1938–39	313.2	1944–45	285.1
1939–40	300.7	1945–46	310.7
1940–41	301.6	1946–47	332.1
1941–42	293.5	1947–48	340.8
1942–43	282.3		

The average daily supply for the year 1938–39 had been the highest recorded up to that time.

This increase and the anticipation of its continuance so long as rehousing and the extension of modern sanitary equipment continued, prompted the Works and Stores Committee to report to the Board in April, 1948, on existing and proposed sources of supply. They felt that the works already planned would now be insufficient to satisfy requirements in years when the Thames and Lee were abnormally low.

The problem was also accentuated by the fact that in recent years there had been periods of two successive dry summers with an intervening dry winter. If in such circumstances the

THAMES VALLEY WORKS



This plan is based upon the Ordnance Survey Map with the sanction of the Controller of H.M. Stationery Office.

H. F. CRONIN M.I.C.E.
CHIEF ENGINEER.

consumption were to continue increasing at the then rate it might be difficult for the Board to replenish their reservoirs in time for the second summer's demands. The proposed reservoirs at Walton, Wraysbury and Datchet would have been adequate for a limited time, but for the unexpected increase in consumption, and as no other sites were available near London it was considered advisable to plan for sources which would solve the problem for many years. Having considered various alternative suggestions, the most economical and practical proposal appeared to be to construct a large impounding reservoir in the Enborne valley several miles south-west of Reading, connected by a conduit to an intake and pumping station on the Thames at Pangbourne. A scheme on similar lines had been considered earlier by Mr. Bryan and is referred to on page 104. The water would be pumped into this reservoir from Pangbourne and would flow back again along the same conduit into the river when the flow at the Board's intakes in the lower reaches was insufficient to maintain the supply without drawing heavily on the existing reservoirs. The Enborne reservoir would cover an area of about 9 square miles, and would contain over three times the joint capacity of the proposed reservoirs at Walton, Wraysbury and Datchet at less than their total cost. This reservoir alone would safeguard the Board against any foreseeable increase in the supply, provided that special arrangements were available for refilling the Board's reservoirs, if necessary, during those periods when a dry summer might be followed by a dry winter. For this purpose it was proposed that during such a winter the amount of the statutory flow at Teddington Weir should, when required, be reduced.

With the Enborne reservoir and increased powers of winter abstraction the construction of the Walton, Wraysbury and Datchet reservoirs could be abandoned, but it was considered that the land should be retained by the Board.

Extensive and prolonged geological investigations in the Enborne valley proceeded from 1947 to 1949.

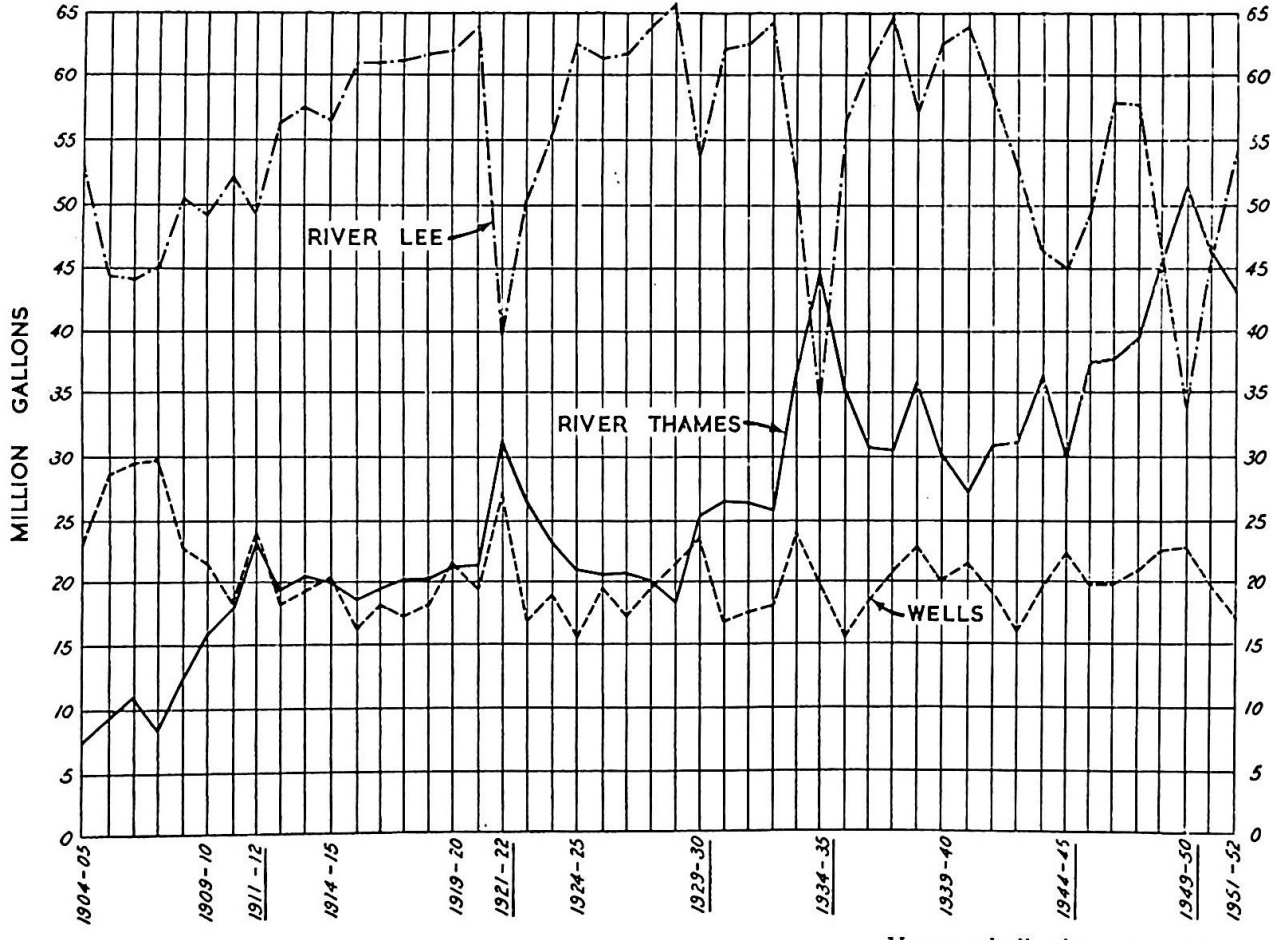
In October, 1949, the results of these investigations were considered by the Board. The intention had been that the Enborne valley reservoir should contain some 55,000 million gallons (about eight times the capacity of the Queen Mary

reservoir) and be formed by building a dam about 4,000 feet in length and with a maximum height of about 100 feet across a narrow portion of the lower or eastern end of the valley at Brimpton. This would impound the water up to a level of 300 feet above O.D. The water area would be about 9 square miles. Subsequently three further dams, which would carry the principal roads, were to divide the reservoir into four sections. A series of detailed reports by experts on the biological aspects of the proposed reservoir showed that thermal stratification of the water would normally occur in the summer and would make the lower layer foul and therefore unsuitable for the Board's purposes. Furthermore, in certain climatic conditions the water would "turn over," that is, the lower layer would rise and mix with the remainder of the water, and the whole would thus be rendered temporarily unusable. In addition the biological quality of the water could never be guaranteed to be of a standard required for discharge into a river. That portion of the scheme to return water to the river from the reservoir could not therefore be considered and would have to be abandoned.

The Chief Engineer had prepared an alternative scheme for constructing the reservoir with the same capacity, but built in two stages, the first stage having a capacity of about 20,000 million gallons. Under this scheme the water would be conveyed direct to the purification works by an aqueduct instead of being emptied into the river. The cost, however, would have been considerably increased and the Enborne scheme therefore lost its attraction.

Having regard to the biological research into the Enborne scheme it now appeared advisable to make the three storage reservoirs in the Thames valley less deep than was originally planned. This would reduce their combined capacity from 16,400 to about 14,000 million gallons. On the basis of the 1944 drought these reservoirs would yield about 66 million gallons daily, as against 100 million gallons daily for the first three sections of the Enborne valley reservoir, and 253 million gallons daily for the complete Enborne scheme.

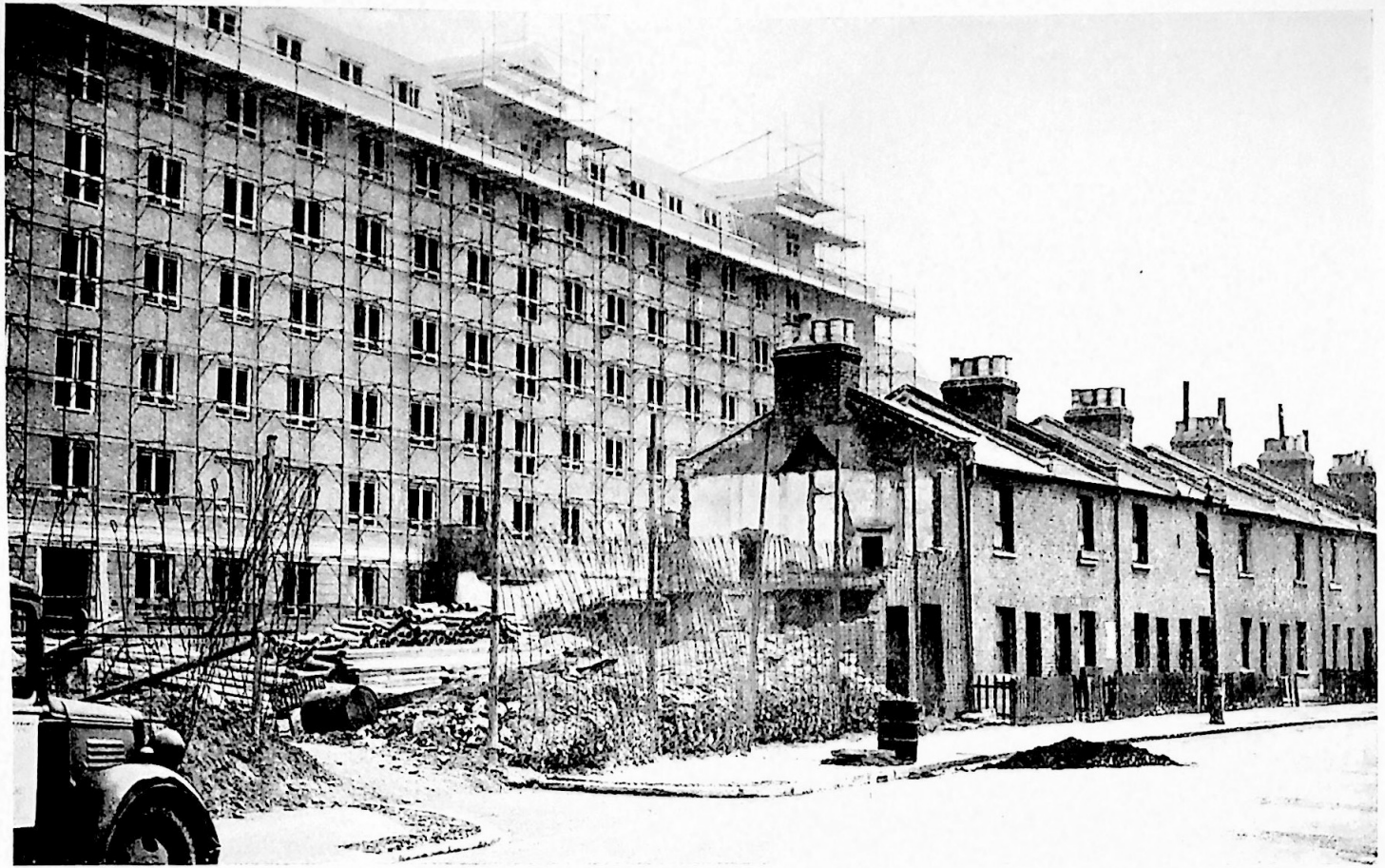
If it had been possible to proceed with the Enborne scheme as originally intended its relatively low cost as compared with the three Thames valley reservoirs, and the extensive storage it would have provided, would have justified the Board in seeking



Years underlined are drought years

SUPPLY TO THE CENTRAL AND EASTERN AREAS

The increasing use of Thames water may be observed



AN EXAMPLE OF POST-WAR HOUSING DEVELOPMENT

powers from Parliament for its construction, but in view of these investigations the Board decided to revert to the policy of the "Progressive Scheme."

The total cost incurred by the Board in connection with the Enborne scheme investigations amounted to £74,736.

75-inch Thames–Lee Valley Main

Difficulty has been experienced in every drought in maintaining the supply to east London because the flow of the Lee is greatly reduced in dry summers, and during the ensuing winters is frequently insufficient either for maintaining the supply or for refilling the reservoirs. This makes it unsafe to empty the reservoirs in the summer. Even now, with the completion of the William Girling reservoir, the yield from the Lee in drought periods is not likely to be more than 46 million gallons a day.

Before the last war, thousands of houses in east London had only a single cold tap over the kitchen sink but with the extensive rehousing programmes undertaken since, it is only a matter of time before many of the buildings will be replaced by modern dwellings, each with an adequate water system. An appreciable increase in the demand for water is therefore to be expected. Moreover, the construction of satellite towns at Stevenage and Harlow and the discharge of sewage effluent from the Rye Meads works, which have been extended to deal with the whole of the sewage originating in the Middle Lee valley, will reduce the amount of water available for abstraction by a figure which it is estimated may reach 12 million gallons a day.

In order to make good the deficiency of the Lee supply when a drought occurs, the Board have relied on a reserve of filtration plant and pumping machinery in the Thames valley, together with mains across London, to transfer larger quantities than usual of Thames derived filtered water to east London. Such an arrangement involves the upkeep of plant not required in years of average rainfall, while in years of drought the Lee valley plant can only be partly used. Moreover, experience has shown that much of the surplus water from the Thames works meets increased demands from districts on the way and is not always available for east London when most needed.

The question of increasing the supply to east London was considered in the Enborne valley report (see p. 146) laid before the Board in April, 1948, and a proposal was made that a large main should be laid to enable raw Thames water to be pumped to the Lee valley. The sinking of trial boreholes for preliminary investigations was then authorised, and in the following December, after a detailed report on the subject had been considered, the Board decided to construct a new Thames intake and to lay a 60-inch main mostly in deep tunnel from Hampton to the south end of King George's reservoir, Chingford, a distance of $22\frac{1}{2}$ miles.

The total cost of the main based on 1948 figures was estimated at £3,855,000 and the Board decided to apply for a government grant towards the cost of the work since the need for this main arose partly on account of a national policy in regard to the siting of new towns.

During subsequent discussions with the Ministry of Health (now the Ministry of Housing and Local Government), a number of alternative suggestions were made of which the principal one was to construct the main to a diameter of 75 inches, in order to provide for possible future developments, since there was great difficulty in forecasting for how long a 60-inch main would suffice.

The question was investigated as to whether it would be better to make provision for possible development by laying a larger main or to duplicate the smaller one at a later date. If the 60-inch main were duplicated in, say, 25 years' time, the aggregate expenditure in capital and running costs over 75 years (that is the termination of the repayment period for the second main) would be greater than if a 75-inch main were laid. Should it not be necessary to duplicate the main the cost would be substantially the same for a 60-inch as for a 75-inch main, the reason being that pumping costs would be lower in the case of the larger main.

The Board finally decided that the main should be of 75 inches internal diameter. The additional cost was estimated at £1,090,000, exclusive of pumping machinery and buildings.

The route will take a fairly straight line and the tunnel, passing under streets and private property alike, will cause a minimum of disturbance to the surface or to traffic. Connections

will be made to the reservoirs at Barn Elms, at Stoke Newington and in the Lee valley.

This main will enhance the usefulness of the Lee valley reservoirs, for not only will it be possible to ensure that substantial quantities of Thames derived water will be available for east London during a dry summer, but after a dry summer these reservoirs can also be filled from the Thames. The main will increase in value as the Lee flow decreases.

The Board's staff have had no experience in the specialised work of tunnelling under London, and in consequence Sir William Halcrow and Partners, experts in works of this nature, have been engaged to undertake surveys, preparation of necessary plans, etc., and the design and construction of the main.

The laying of this main involves engineering problems of exceptional interest as, for example, the lining of the tunnel and the manipulation of the large diameter pipes underground.

The successful completion of a 1,000-foot experimental length of main in tunnel has demonstrated that the proposed design for the full length main is not only a practicable proposition, but that the main can be built safely and expeditiously and at a cost considerably less than by any alternative method. (See photograph facing page 226.)

CHAPTER XIII

Abstraction from Thames and Lee

River Thames

In 1904, six of the water companies were either partly or wholly dependent on the Thames for their supply, and the New River Company had recently taken steps, by joining the Staines Reservoirs Joint Committee and embarking on communication works at Kempton Park, to draw on the river in their turn. Each company had its own intake and its own arrangement with the Thames Conservancy, confirmed by Acts of Parliament, the provisions of which were relatively simple as far as each company was concerned, but complicated in the extreme when taken *en masse*, as they were by the Board.

Briefly the position was this. The Chelsea Company were authorised to take up to 22 million gallons a day and the West Middlesex and Grand Junction Companies were each allowed to draw up to $24\frac{1}{2}$ million gallons.

The East London Company were entitled to take up to 10 million gallons a day but if the river was above a specified flood level the quantity that could be taken was unlimited. This level was so high as to make this right practically valueless. In an emergency and with the sanction of the Local Government Board an additional 30 million gallons a day could be taken provided this did not exceed an average of 10 million gallons a day over a half-year. This "excess water" could not be taken at all if the flow over Molesey Weir was under 190 million gallons a day.

The Lambeth Company were authorised to draw up to $24\frac{1}{2}$ million gallons a day from the river and a further amount from the gravel at Molesey equal to a daily average of $7\frac{1}{2}$ million gallons over a half-year. When the flow was over 190 million gallons a day at Molesey Weir the company were entitled to take a further quantity up to 100 million gallons a day provided that the total amount drawn in any half-year did not exceed

an average of 20½ million gallons a day, and that the flow was not reduced below 190 million gallons.

The Southwark and Vauxhall Company were entitled to draw a daily average of 45 million gallons per half-year and within that limitation they could draw up to 100 million gallons in any day. If, however, the flow over Penton Hook Weir was at a lower rate than 285 million gallons a day the company were prohibited from drawing more than 24½ million gallons, but when the flow over the weir was higher than 285 million gallons the Company were entitled to take all water in excess of that flow.

The Staines Reservoirs Joint Committee were entitled to draw up to 100 million gallons on any day provided they did not reduce the flow over Bell Weir below 265 million gallons. Moreover, the supply from the reservoirs was restricted to 35 million gallons a day except that, in case of emergency, the Local Government Board could permit them to withdraw up to 45 million gallons a day from the reservoirs.

As the result of these agreements the Board possessed an unrestricted right to 130 million gallons per day, irrespective of the condition of the flow and a maximum quantity of 435½ million gallons in any one day.

The Board's scheme for future supplies and the promotion of their (New Works) Bill, 1911, necessarily involved a review of the conditions under which they were entitled to abstract water from the Thames. Negotiations were entered into with the Thames Conservancy in order to agree the conditions under which additional abstraction powers should be obtained from Parliament for future supply. An agreement was arrived at between the two parties which was embodied in clauses in the Thames Conservancy Bill, 1911.

Under this agreement the Board proposed to surrender their right to an unrestricted supply of 130 million gallons a day, and refrain from abstracting water at any time when the flow over Teddington Weir was less than 140 million gallons a day, after they had constructed further storage. When the Board's Bill came before the Joint Committee of both Houses, reference was made to this agreement and there was strong opposition from certain authorities who insisted on a minimum flow of 200 million gallons. Eventually the Committee decided that

they would be unable to allow the Board's Bill to proceed, unless the minimum flow figure of 140 million gallons was amended to 170 million gallons. The Board then decided to reconsider the matter and at one time were on the point of withdrawing the Bill altogether, but having considered that the limitation was bound to be inserted in the Thames Conservancy's Bill, since that Bill was also before the Joint Committee, they eventually decided to accept it.

The relevant section of the Thames Conservancy Act, 1911, when passed, permitted the Board to retain their unrestricted right to 130 million gallons a day until 18th August, 1918, or until the Board had completed new storage capacity of 1,000 million gallons. Excess water could be taken subject to a minimum flow of 200 million gallons over Teddington Weir but the maximum quantity in any one day was not to exceed 1,200 million gallons. The average daily quantity during the year was restricted to 230 million gallons until further storage was authorised when it would be raised to 300 million gallons. After the construction of 1,000 million gallons of storage or after the 18th August, 1918, no more water was to be abstracted when the actual flow over Teddington Weir was less than 170 million gallons, but the flow could be reduced to 140 million gallons with the sanction of the Local Government Board. Water could not be abstracted from above Penton Hook Weir unless the flow there exceeded 285 million gallons. If the flow exceeded that figure the following scale applied: between 285 and 385 million gallons, all water in excess of 285 million gallons could be taken; between 385 and 815 million gallons, in addition to the 100 million gallons already allowed, half the flow above 385 million gallons; above 815 million gallons a day, in addition to the above quantities, all water in excess of 815 million gallons. The Board were allowed to take gravel water, which was not to be deemed part of the quantity to be taken from the Thames, but it could not be extracted when the flow over Teddington Weir was less than 170 million gallons per day. No abstraction was allowed between Penton Hook and Shepperton Weirs when the actual flow was less than 150 million gallons a day ascertained as directed by section 162(7) of the Act.

The date for bringing into force the new regulations was subsequently postponed by Orders of the Local Government

Board and the Ministry of Health until 18th August, 1926. This was due to the delay in completing the Queen Mary reservoir.

The same regulations were embodied in the Thames Conservancy Act of 1932, but, as indicated below, they have been modified subsequently.

The authorisation of further storage in the Thames valley by the 1935 Act increased to 300 million gallons the daily average amount which the Board were entitled to abstract.

This Act also allowed the Board, with the consent of the Port of London Authority, to reduce the statutory flow at Teddington from 170 to 140 million gallons a day. This power was limited to 8 years from the passing of the Act. An extension to 11 years was granted by Ministerial Order in 1943, so that it expired on 2nd August, 1946.

As the result of the 1946 Act, which authorised the construction of reservoirs at Wraysbury and Datchet, the Board will be allowed to take an average daily amount of 400 million gallons when either of these reservoirs is ready to be filled. The same Act limits the average daily quantity to 330 million gallons between 1st May and 31st October, and the provisions relating to abstraction above Penton Hook Weir are repealed, except that abstraction above the Weir is prohibited when the flow there is less than 285 million gallons a day.

In January, 1948, the Board applied for an Order under the Water Act, 1945, to amend the Thames Conservancy Act of 1932, so as to enable the Board to reduce the statutory flow over Teddington Weir from 170 million gallons a day, during the period 1st February to 31st May in any year, (*a*) to 140 million gallons at the Board's discretion and (*b*) to 90 million gallons with the consent of the Minister. This power would enable the Board to enter the month of June in each year with their storage reservoirs as full as possible.

A number of objections were received to the proposed Order, the most outstanding of which were considered at an Inquiry held on 3rd March, 1949, by an Inspector of the Ministry of Health. An Order, substantially in the terms applied for by the Board, was made by the Minister of Health on 9th May, 1949.

With regard to the statutory flow of 170 million gallons over Teddington Weir, Orders have been made during drought

periods from time to time for this flow to be diminished (see p. 159).

Payments to the Thames Conservancy for water taken from the River and from gravel beds have increased considerably since the Board took over in 1904, as the following table shows:

Year.	Amount per annum.	Authority.
	Minimum Maximum	
Before 1911 ...	£25,450—£40,219 10s. od.*	Agreements and various Acts.
	£ s. d.	
1911	33,402 3 9	Thames Conservancy Act, 1911.
1912–19	40,000 0 0	,,
1920	45,000 0 0	,,
1921–24	112,500 0 0	Thames Conservancy Act, 1921.
1925 to March, 1948	90,000 0 0	Thames Conservancy Acts, 1924 & 1932.
April, 1948 to December, 1950.	176,860 0 0	S.R. & O. 2534/1947 (Defence Regulation 56).
1951	175,500 0 0	Thames Conservancy Act, 1950.

*Excluding £1,410 in respect of gravel water.

River Lee

The regulations governing abstraction from the Lee were laid down in the River Lee Water Act, 1855. Under this Act the New River and East London Companies were authorised to divide between them, in certain proportions, the whole flow of the Lee with the exception of certain maximum daily quantities set out below which are reserved for navigation :

Above and including the first Lock above Feilde's Weir	3·6	million gallons
From the above Lock down to and including Waltham Town Lock	4·5	,, ,,
From Waltham Town Lock down to and including Old Ford Lock	5·4	,, ,,

and subject also to the maintenance of the customary head

levels. In practice, therefore, the Board are entitled to take the whole of the flow except that required for lockage. Abstraction through the New River Company's intake at New Gauge, Hertford, was limited, however, by section 21 of the Act of 1855 to 22½ million gallons a day. This restriction was relaxed by an Order made in 1944, by which the Board were allowed to draw up to 32½ million gallons at New Gauge when the flow at Feilde's Weir was not less than 35 million gallons a day. This provision was subsequently embodied in the Board's Act of 1946.

When the Board first took over, sums of £8,000 for abstraction and £2,000 for protection of the water were payable to the Lee Conservancy Board under their Acts of 1868 and 1900. These sums were increased to maximum payments of £20,000 and £4,000 respectively by the Lee Conservancy Act, 1921, which provided that these payments should obtain for a period of five years only from the date of the passing of the Act. Subsequent extensions of these provisions were to be made by Joint Ministerial Orders. In 1926, the contribution for abstraction was reduced to £18,000 and as from 24th June, 1929, to £16,000. This last reduction was the result of an agreement between the two Boards in pursuance of which the Water Board had loaned £60,000 to the Conservancy Board to enable them to carry out works for the improvement of the navigation. In 1931 the contribution was raised to £17,000, where it remained until 1941. In 1941, in order to meet special circumstances brought about by the War, the contribution was raised to £22,667 for the year ending 25th June, 1941 and £20,000 for the next five years. For protection of the water the Board had made payments to the Conservancy Board varying between £3,000 and £4,000 per annum according to the anticipated expenditure for the particular year under review. The Conservancy Board were under a statutory obligation to submit an estimate of their anticipated expenditure under this head to the Board each year.

The last Order under the Conservancy Board's 1921 Act expired on 24th June, 1946. Following negotiations, the Board, with the sanction of the Ministry of Health, agreed in December, 1947, to pay the Conservancy Board just under £30,400 for abstraction and £10,118 for protection of water for the periods

25th June, 1946, to 31st December, 1947, and 1st April, 1946, to 31st December, 1947, respectively.

On 1st January, 1948, the undertaking of the Lee Conservancy Board became vested in the British Transport Commission and with the exception of water protection activities, the functions formerly carried out by the Conservancy Board were taken over by the Commission who thus became entitled to payments from the Board for abstraction of water. From 1st January, 1948, the Board's payments to the Commission reverted to the old rate of £8,000 per annum, the amount prescribed by the Lee Conservancy Act of 1900. In the following year, however, the Commission introduced a Bill in Parliament for raising the Board's contribution to an annual payment of £25,500 per annum as from 1st January, 1948. The Board petitioned against this provision and the matter came before a Committee of the House of Lords in July, 1949. The Committee decided that the proposed contribution was justified and the Bill received the Royal Assent on 30th July, 1949.

Since January, 1949, payment for protection of water is made to the Lee Conservancy Catchment Board. For the year 1948, the Water Board, with the sanction of the Minister of Health, approved in November of that year a payment of £6,277, the estimated amount required by the Catchment Board. To this sum a further £695 was added in June, 1949. In April, 1949, the Catchment Board obtained a Ministerial Order increasing the Board's contribution to a maximum of £7,000 per annum for the years beginning January, 1949 and 1950. Payments under this Order of £6,917 for the year 1949 and £6,827 for the year 1950 have since been made. In 1950 the Lee Conservancy Catchment Board Act was passed which extends the limitation of £7,000 per annum to 31st March, 1953. After that date the maximum payment by the Board to the Catchment Board is to be agreed by the two Boards or, in the absence of agreement, determined by the Minister of Housing and Local Government. Negotiations to that end are now proceeding.

CHAPTER XIV

Droughts

BROADLY speaking, the Board obtain about two-thirds of their supply from the Thames, one-sixth from the Lee and one-sixth from springs and wells. These proportions do not obtain, however, during dry periods, when the supply from the Lee often is substantially diminished. For instance, during the hot and dry summer of 1949, from June to October inclusive, the proportions were seven-tenths from the Thames, nearly one-fifth from wells and less than one-tenth from the Lee.

This dependence on river-derived supplies naturally leads the Board to consider a drought in terms of low river flows and, therefore, although the definition of an absolute drought is "a period of at least fifteen days, to none of which is credited 0.01 of an inch of rain or more," the word is customarily used by the Board to indicate a period when low flows in either the Thames or the Lee compel the withdrawal of large quantities of water from the storage reservoirs. It has this second meaning in the present context.

A prolonged period of drought, when accompanied by rising consumption, can be a time of considerable anxiety especially when reserves are strictly limited. In reporting on the drought of 1949, Mr. H. F. Cronin, the Chief Engineer, observed as follows: "During a drought the picture of the future is blank, and in view of the serious consequences which would occur if the reservoirs were emptied before the flow in the river rose, the tendency is, and the policy must be, to play for safety and to take no chances." It is in the light of droughts that the Board have formulated their policy for the construction of storage reservoirs, which are the foundation of London's water supply.

There have been six droughts during the past fifty years, namely those of 1911, 1921, 1929, 1934, 1944 and 1949. To bring them into proper perspective it is necessary to bear the following facts in mind.

Up to 1926 there was no "statutory minimum flow" of 170 million gallons per day in relation to the River Thames. Secondly, it was not until 1926, that is, well after the drought of 1921, that the Queen Mary reservoir at Littleton was brought into use. Thirdly, in 1911, the whole storage position, but particularly that in the Lee valley, was vastly different from what it is today. The total storage, including balancing and subsidence reservoirs, in the Lee valley, amounted to 2,499 million gallons as against 8,968 million gallons today, whilst the corresponding figure for the Thames valley was 6,345 million gallons as compared with 18,299 million gallons today.

Actual experience is a realistic teacher. Up to 1920 the Board had only the records of the 1899 and 1911 droughts, whereas since then droughts of much greater intensity have been experienced.

The droughts of 1911 and 1929 were not serious but should be included for the sake of this record. In the first case the yield of the River Lee diminished considerably and it was necessary to draw upon the Walthamstow reservoirs on 21st July, 1911. At the then rate of withdrawal these reservoirs would have been exhausted within the short space of six weeks and it was, in consequence, necessary to transfer increasing quantities of Thames water. By 12th September some 20 million gallons per day of Thames water were being pumped to the Lee valley. In those days this was a considerable quantity. The consumption rose to just over 300 million gallons per day during the week of maximum demand, i.e., ending 28th July, 1911.

The absence of rain during the early months of 1929, resulted in low flows in the Thames and the Lee and a diminution in the yield from the wells, synchronising with a substantial rise in consumption. The Board appealed for voluntary economy but met with little response and were therefore obliged on 19th July, to impose restrictions on the watering of gardens, etc., by hose or sprinkler and the washing of motor vehicles by hose. The latter restrictions were removed on 2nd August and the remainder on 7th October. A remission of a portion of the charges on account of the restricted supply was made, resulting in a loss of income to the Board of approximately £31,000.

It is now proposed to refer to the droughts of 1921, 1934, 1944 and 1949.

It may here be stated that the history is partly in the making and partly in retrospect. Thus, although certain of the flows and other conditions are recorded as they occurred, their relative significance and severity have to be seen in the light of present-day needs. Accordingly, it will be observed that a figure of 408 million gallons per day has a critical significance in relation to the flow of the River Thames. It comprises (i) a statutory minimum flow of 170 million gallons per day over Teddington Weir; (ii) an assumed abstraction of 230 million gallons per day required by the Board (this being approximately the present-day average quantity taken); and (iii) a quantity of 8 million gallons per day abstracted by neighbouring water authorities.

The drought of 1921 was the most prolonged in the Board's history. From 22nd May to 1st December the flow in the Thames was under 408 million gallons a day. It was under 300 million gallons on 123 days and under 200 million gallons on 22 days. Restrictions, however, did not have to be imposed, although an appeal was made to avoid using water for garden purposes, and a partial remission of the charge was subsequently made. An important reason for this relative freedom was that, as already stated, at that time the reservation of a statutory flow of 170 million gallons a day over Teddington Weir had not come into operation. Other reasons were that the supply was much smaller than it is now and the Lee behaved somewhat better than it has subsequently. The daily average quantities supplied from the Thames in the years 1920–21 and 1921–22, were 162.9 and 155.7 million gallons respectively (as compared with the daily averages for the years 1948–49 and 1949–50 of 225.8 and 228.3 million gallons respectively). For the year ending March, 1952, the figure was 219.1 million gallons. The average daily natural flow in the Lee from June to October, 1921, nearly 37 million gallons, was considerably higher than in any other similar period in a drought year.

Ever since the statutory requirement of a minimum flow of 170 million gallons a day over Teddington Weir came into operation in 1926 (see p. 154), the Board have been deficient in storage in the Thames valley. The only means by which the supply has been maintained in subsequent drought years has

been by recourse to the provisions of the Thames Conservancy Act of 1932, by which an Order can be obtained for the temporary reduction of the statutory flow. The maintenance of the supply in a dry summer, therefore, has always been a matter of considerable anxiety. Although a permanent reduction in the statutory flow would reduce the amount of storage required by the Board, this would entail legislation and there is no doubt that strong opposition from other authorities would be encountered. Apart from this, any considerable reduction of the flow would result in the disappearance of an effective, but hidden, reserve. If the storage policy were based on a daily flow of say 50 m.g.d., and if for any reason the construction of the reservoirs were behind schedule, a serious state of affairs would result, as there would then be no reserve upon which the Board could draw. Moreover if the construction of storage reservoirs were up-to-date, on the basis of a statutory flow of 50 million gallons a day, there would be no water available anywhere if one or more of the reservoirs became unusable, or if the drought were of a more severe character than hitherto experienced.

The seriousness of a drought depends on the daily average supply to be provided. The 1921 drought was the most prolonged but not the most serious. If a drought similar to that of 1921 were to recur, 31,300 million gallons of storage would now be required to maintain a daily average Thames supply of 230 million gallons without reducing the statutory flow. The Board's present usable storage capacity in the Thames valley, however, only amounts to 14,997 million gallons. The storage capacity required if the other droughts were to recur, with the same average daily demand, is as follows:

1899	...	...	21,500 million gallons
1934	...	...	31,100 ,, ,,
1944	...	...	28,400 ,, ,,
1949	...	...	21,500 ,, ,,

Taking 1921 as unity, the proportion of this quantity required in the other years is:

1934	...	...	0.99
1944	...	...	0.91
1949	...	...	0.69
1899	...	...	0.69

The drought of 1934 followed a year of high consumption and a relatively dry winter.

At the beginning of April, 1934, the storage reservoirs in the Thames valley were practically full, but the Lee valley reservoirs contained little more than half of their capacity, the shortage of rain during the previous winter having prevented the filling of them. The water-bearing strata in the Thames basin also had not been replenished, and very early in the year it became necessary to draw on the reservoirs in order to maintain the supply.

In view of the steadily diminishing flow of the River Thames, appeals for economy were given the widest publicity and notices were displayed in public vehicles, buildings and hotels and on cinema screens. Local authorities and sports clubs were also asked to reduce to an absolute minimum the quantity used for watering parks and recreation grounds. The supply in the area normally supplied with water from the Lee was maintained by special arrangements made during the winter of 1933–34 for transferring Thames water, but the continued fall in the flow of the Lee increased the need for Thames water, and as the natural flow of the Thames also continued to fall, it became necessary to draw large quantities from the storage reservoirs.

As a long period would have to elapse before rain could replenish the springs feeding the Thames, an application was made on 11th June for an Order under the Thames Conservancy Act, 1932, to reduce the statutory flow, and this was accordingly granted on 22nd June, reducing the flow to 100 million gallons a day.

Another Order was made on 11th July to continue in force until 31st December, reducing the actual flow over Teddington Weir to 50 million gallons a day,

The continuance of the dry period made it necessary to maintain existing reserves, and the Board prohibited as from 27th June, the use of water for watering gardens, etc., by hose or sprinkler and the washing of motor vehicles by hose. As in 1929, a proportion of the charges for these services was remitted at a cost to the Board of £35,860. The restrictions were withdrawn as from 1st October.

In July it was decided to bring into operation two disused wells, Honor Oak and Merton Abbey. Machinery was also

installed to pump water from gravel beds in the Thames valley, and certain works of a permanent character for extracting gravel water were executed.

A period of prolonged deficiency of rainfall occurred in the Thames and Lee valleys from February, 1943, to September, 1944. By April, 1944, it had become clear that failing heavy continuous rain during the summer, the flow of the Thames and Lee would be insufficient to maintain the supply if the statutory flow of 170 million gallons a day at Teddington was to be maintained. Application was therefore made for permission to reduce the statutory flow to 140 million gallons a day. This was granted with effect from 13th May. An undertaking was given on behalf of the Board on 6th June that the amount of water in store would not be increased while the statutory flow was less than 170 million gallons a day.

The average daily flow of the Thames for the month of May was 340 million gallons as compared with the standard average of 1,096 million gallons, and during the early part of June the flow dropped to about 230 million gallons a day.

Every effort was made to obtain the co-operation of consumers in saving water, but on 16th June the Board found it necessary to prohibit the use of water by hose for watering gardens, etc., cleaning vehicles and certain other purposes. A proportion of the charges paid was remitted as usual, the loss of income to the Board being approximately £29,000. A request was also made to water undertakings receiving bulk supplies from the Board to impose, so far as they could, similar restrictions upon their consumers and to make full use of their own resources before resorting to the bulk supply.

Before the statutory flow was reduced, a programme of depletion of the reservoirs, having in mind war conditions, was drawn up. It was decided to aim at the retention of a definite quantity of water in the reservoirs on 31st October, 1944. This was accepted at a conference with the Thames Conservancy and others on 19th June, 1944, held to consider the Board's application for an Order reducing the statutory flow from 140 to 70 million gallons a day. As a result of this conference, an Order was issued on 24th June, 1944, providing for 100 million gallons as the minimum daily flow until 31st October, 1944. A further Order was issued on 3rd July, reducing the minimum

London Laughs at 173

"I wish to give notice that I am changing my bath night from Friday to Saturday night!"

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EAST LONDON WATER SUPPLY!

Company's Turncock. "NOW, LOOK 'ERE, DON'T YOU GO A WASTIN' ALL THIS 'ERE VALUABLE WATER IN WASHIN' AND WATERIN' YOUR GARDENS, OR ANY NONSENSE O' THAT SORT, OR YOU 'LL GET YOURSELVES INTO TROUBLE!"

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daily flow to 50 million gallons but it was provided that the abstraction from the Thames had to be so regulated that the total combined volume in store did not exceed the agreed diminishing storage figure.

In October, 1944, in view of the improved Thames flow, the Board informed the appropriate authorities that they did not propose to apply for an extension of the Order after 31st October, 1944, and that they no longer required to reduce the statutory flow to 140 million gallons.

Restrictions on the use of water for non-domestic purposes were withdrawn with effect from 1st November, 1944.

In June, 1944, the Board decided that the drought conditions of 1899 should serve as the basis to be provided for entirely by storage. To safeguard the Thames-derived supply in a 1921 drought would require the assistance of a reduction in the statutory flow. Shortly after this decision, the flows in the river fell to figures comparable with those of 1921 and 1934 and, as a consequence, doubts were raised as to whether the Board were making sufficient provision for the future if they based their calculations on 1899 river flows.

An analysis of all the relevant data was subsequently made, and in January, 1947, the Board decided to adopt the river flows of 1944 and not those of 1899 as the basis upon which they should endeavour either to provide storage accommodation in the Thames valley or to seek additional powers to construct other works to increase the supply. The adoption of this basis with an average daily Thames supply of 230 million gallons requires some 28,400 million gallons of storage.

Early in 1949 it became evident that the summer supply could not be maintained with the existing statutory flow, and application was therefore made for an Order for its reduction. Under this Order, made on 2nd July, the reduction of the flow was to be determined by reference to a table relating the flow to the amount of water in store. The calculations upon which the table was based assumed that the flows would be as in 1921 and the supply as in 1947, i.e. the worst conditions of flow and the highest demand. The Order provided that the Board should not use the powers of the Order to increase the amount of water in store.

Record low flows occurred during the early part of September, which necessitated heavy withdrawals from reservoirs, the total figure for the period 5th–12th September being no less than 1,461 million gallons. If this continued there was a grave risk of the reservoirs being so seriously depleted as not to last out if the drought continued into November. A further application was therefore made under the Thames Conservancy Act, 1932, for permission to reduce the flow to 50 million gallons a day, and this was granted on 19th September. The weather broke soon after, and the provisions of the Order were not required after the 8th October. As a result of the two Orders, the Board could, in theory, have abstracted 9,720 million gallons more than if the statutory minimum flow of 170 million gallons a day had been strictly observed. It is, however, almost impossible to regulate the abstraction so as to maintain the gauged flow exactly at a predetermined amount. In the drought under review, only 8,122 million gallons, or 83 per cent. of the "extra" water, were actually taken.

On 2nd July, 1949, concurrently with the issue of the first Order authorising the reduction of the statutory flow, the Board imposed restrictions on the use of water for certain non-domestic purposes subject, however, to the concession that garden watering and car washing by means of a hose were permitted on Sundays and Wednesdays. This obtained until 16th September, when the concession had to be withdrawn and full restrictions came into force. Restrictions were cancelled on 26th October. On this occasion approximately £31,000 was remitted because of the restricted supply.

As usual during drought periods, practically all the Lee flow was abstracted by the Board. Over the five critical months, June to October, the amount obtained—19 million gallons a day on average—was as low as in 1934 and considerably lower than in 1944 or 1921. Large quantities were taken from the Lee valley reservoirs.

Propaganda during Droughts

Experience has shown that the supply in a drought year is considerably less than in the preceding year, owing to restrictions, propaganda and publicity. The figures for 1920–22 and 1933–35 bear this out, the reduction in consumption being

about 10 per cent. The 1944 drought occurred in the war period when conditions were abnormal. In the case of that of 1949 the reduction in supply as compared with the preceding year 1948–49 was only 2 per cent.

In 1921, pressure was reduced in the mains and a reduction was obtained in the amount of water used for street watering and other public purposes, as well as for garden watering. Owing to re-zoning it is not now possible to reduce pressures without depriving consumers of water.

In the winter of 1933–34, when it became obvious that there would be difficulties during the ensuing summer, the Board commenced extensive propaganda, and the watering of gardens, etc., by hose and the washing of motor cars, was prohibited from 27th June, 1934. The publicity campaign was continued, warning the public by brief and direct statements that there was a severe shortage of water and exhorting them to use less.

Similar restrictions and a similar advertising campaign were put into force in 1944.

In 1949, however, a different policy was adopted and until the 16th September, the Board, although prohibiting the use of a sprinkler, allowed the use of a hose for garden watering and car washing on Sundays and Wednesdays. The effect of this concession was to increase the supply on those two days. The propaganda was by no means as intensive as in 1934 and 1944, the motif being "Use what you require but do not waste."

The following table gives the estimated saving effected by restrictions:

Year	*Average daily quantity million gallons*	*Total for the year million gallons*
1921–22	9	3,300
1933–34	15	5,500
1949–50	6	2,200

Depletion of reservoirs

The extent to which it was necessary to deplete the reservoirs during the drought years varied according to the circumstances of each case.

Dealing first with those in the Lee valley. In the 1921 and 1949 droughts, 2,878 and 2,893 million gallons were withdrawn, but in 1934 and 1944 the quantities were only 1,133 and 1,918

million gallons. The explanation is as follows: Until King George's reservoir, Chingford, was completed in 1913, the storage in the Lee valley was relatively small and in no winter would there have been any difficulty in refilling it. Thus, so far as the operation of the reservoirs was concerned, the available experience showed that it would be quite safe to draw them right down in any dry summer and refill them again by the following spring. This was done in 1921 and 1929.

In October, 1933, the reservoirs were nearly empty, and the winter flows of 1933–34 were so low that it became evident early in 1934 that it would not be possible to refill them. In consequence, the Board authorised the installation of additional pumping plant and connections to enable extra quantities of Thames water to be transferred to east London. At the commencement of the summer of 1934, the Lee valley reservoirs were only about two-thirds full, and as a result of this experience it is now the practice to attempt to limit the withdrawal of water in a dry summer to about half the total capacity. In 1945, because the previous year was one of severe drought and it was unlikely that a third year of severe drought would follow, considerably more than half the storage was withdrawn.

In 1949 rather more storage was used than appeared advisable, but the Board had no choice in the matter because it was impossible to pump any further quantities of Thames water to east London. The risk had to be taken and the Lee valley reservoirs were drawn down from about 4,300 to below 1,500 million gallons.

The depletion of the Thames valley storage reservoirs during the drought years was as follows:

Year	*Depletion*
1921	1,529 million gallons
1934	3,347 ,, ,,
1944	6,633 ,, ,,
1949	9,905 ,, ,,

It will be noted that considerably more water was drawn from the reservoirs in 1949 than in 1944, King George VI reservoir having been brought into use between those years. Little water was drawn in 1921, because there was no statutory restriction on the flow at Teddington.

In regulating the withdrawal of water from storage during a drought, when it is known that the reservoir capacity is insufficient for requirements and the end of the period of low flows is not known, it is difficult to regard with equanimity the withdrawal of very large volumes of water as, for example, at the rate of 200 million gallons a day, especially when the river flow is lower than had been anticipated. This happened in September, 1949, and although it may appear in the light of after events that the Board acted precipitately in asking for an Order to reduce the flow still further, the situation at that time justified the precautionary measures which were taken.

CHAPTER XV

The Kent Area

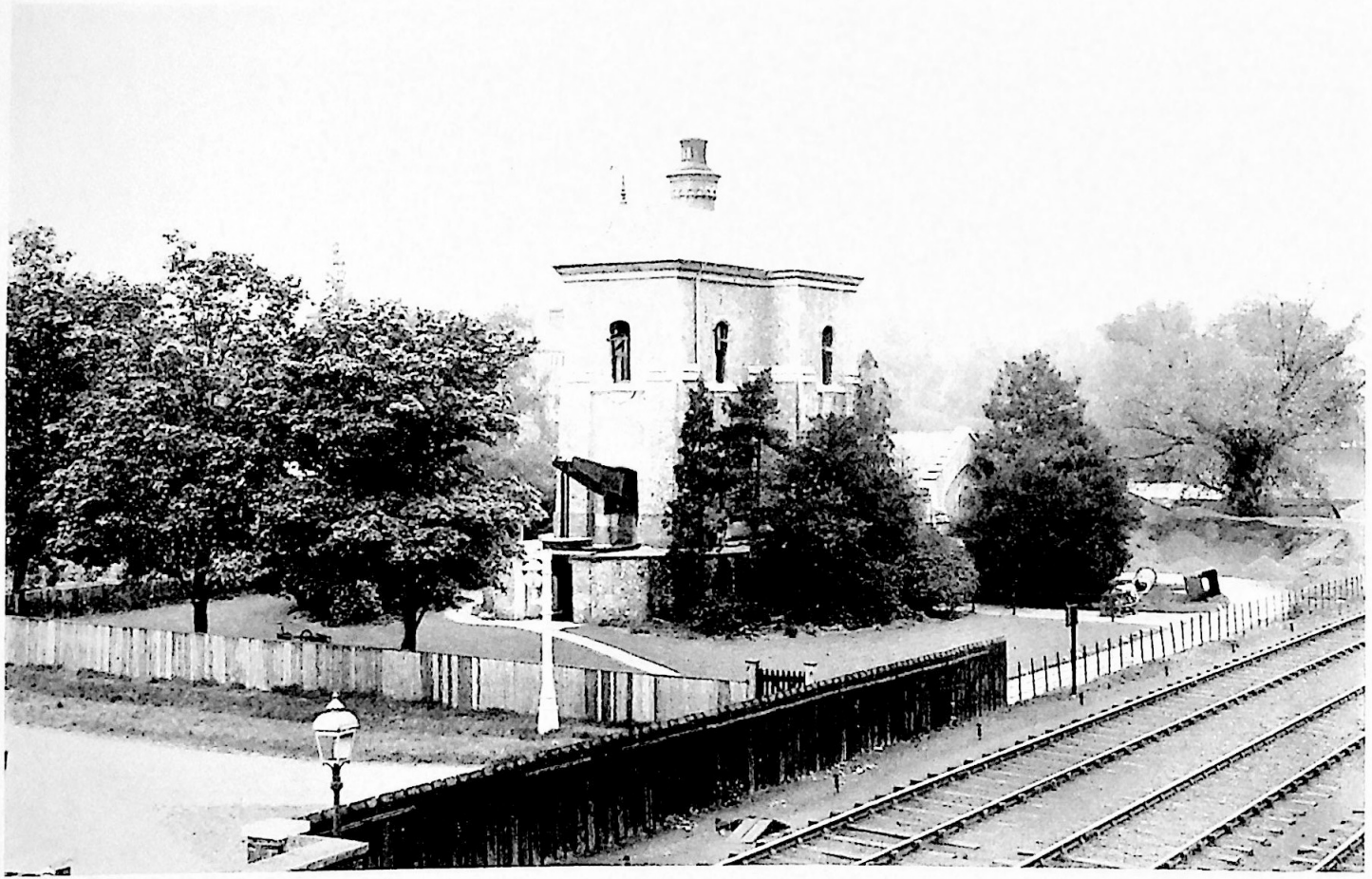
In 1904 the Kent Company's area, which became the Board's Kent district, extended to Southfleet on the east and to Edenbridge on the south. It had an area of 179 square miles and a population of 632,000. The supply was obtained from 20 wells in various parts of the district, and there were 17 covered service reservoirs having a total capacity of slightly over 15 million gallons. Of these, the elevated reservoirs had a total capacity of 13 million gallons. The wells were far apart, and the height to which water had to be pumped varied from the top storeys of premises at the level of the river Thames to premises supplied from the Westerham Hill reservoir, the top water level of which is 818 feet above Ordnance Datum.

The average daily supply in the area was approximately 19 million gallons in 1904–05. In 1951–52 it was 41 million gallons. This remarkable increase and the way the Board have met it is the subject of the present chapter. It will be seen that it has involved the sinking of many new wells, the modernisation of those already in use, and the infusion into the area of large quantities of Thames-derived water.

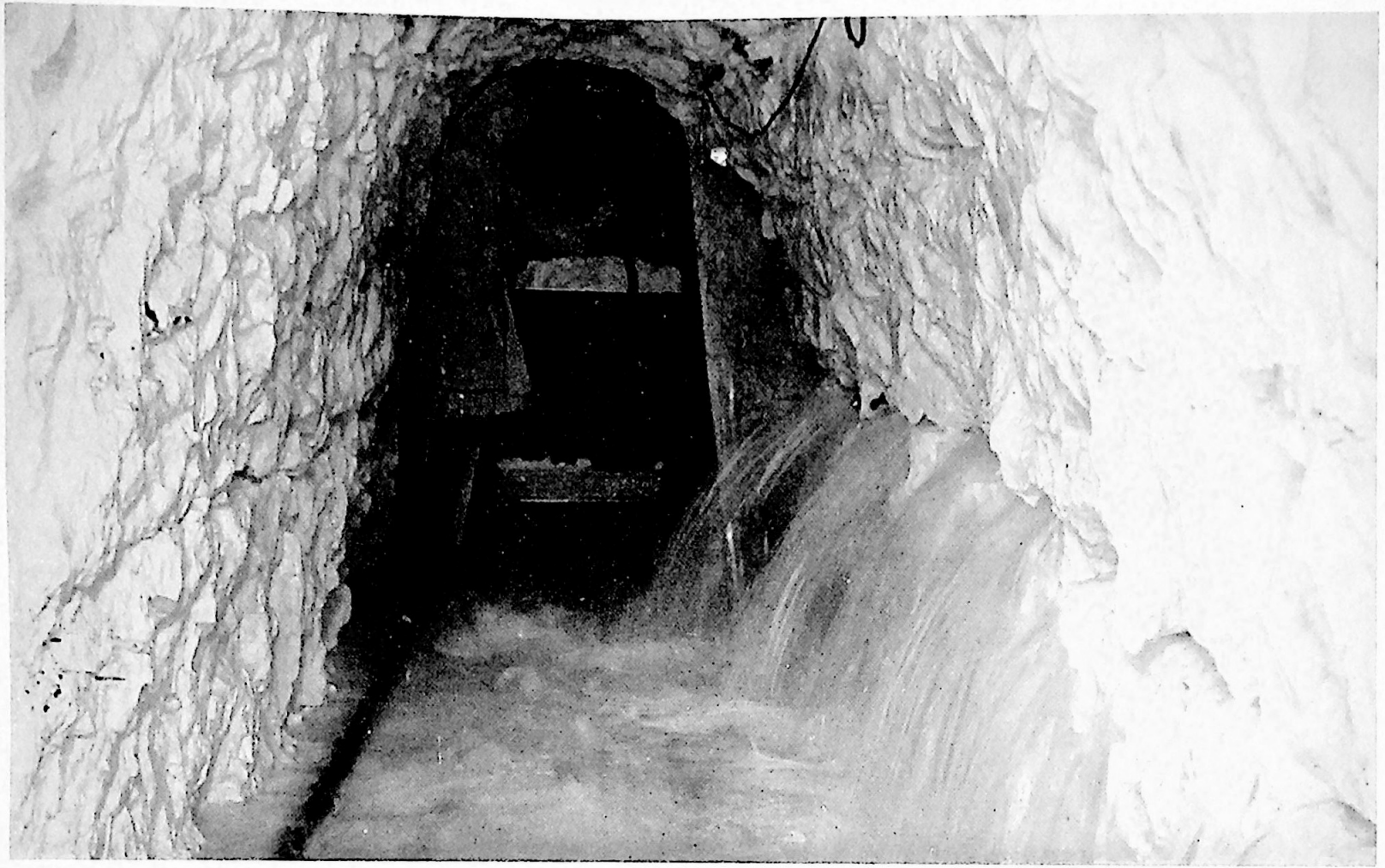
The Kent district supply differed from those in the Board's other districts there being no storage reservoirs in that district. Demands above the average during the summer months necessitated having a number of wells in reserve, over and above those needed for maintaining the supply in the event of a breakdown or other stoppage of the engines for overhaul and repair.

Several of the stations taken over by the Board were without duplicate engines, so that when a stoppage occurred there was a risk of difficulty in maintaining the supply from other and distant wells and through long lengths of pipes of small diameter.

Some assistance could be obtained from the Thames valley stations through a 36-inch intercommunication main running



SHORTLANDS PUMPING STATION ABOUT 1910
Showing projecting beam of Cornish engine



WELL HEADING IN CHALK

between the Southern district works at Nunhead and the Eastern district on the north side of the Thames, which was connected to the Deptford works of the Kent district by a 24-inch main. A period of maximum demand in the Kent district might, however, coincide with a similar period in the Southern district and if this occurred, and it was quite likely to, there would be no margin left for the Kent district. There was also the possibility of the large mains in the Southern district being out of use during a period of drought.

By and large, therefore, the maintenance of a full supply at times of maximum demand was precarious. Certain proposals were adopted by the Board in February, 1911, in order to increase the resources in the district. They included the installation of machinery at a borehole at Green Street Green, started by the former Kent Company, and the sinking of an additional well on the Board's property at Shortlands and the installation of modern machinery there. The use of modern machinery at Shortlands, which would have a capacity of 2½ million gallons a day, would enable the quantity of water pumped from the well to be raised to the same height with a consumption of one half the quantity of coal then consumed at the station. Of these works, the well and station at Green Street Green, containing the Board's first diesel engines, were completed and brought into use early in 1914.

The Local Government Board were unable to see their way to sanction the raising of the necessary loan for the construction of the well at Shortlands, as they considered that the work was not within the Board's statutory powers. In view of the urgency of this work, which was intended to safeguard the supply to the Bromley area, the Board decided in July, 1912, to proceed and to charge the cost against the sum of one million pounds which they were authorised to borrow under their New Works Act of 1911.

At that time the maximum yield of the Kent wells, after continuous pumping to meet demands in dry weather, was 27 million gallons a day. A quantity in excess of this had been afforded during the maximum week of 1911, but only at the expense of serious depletion of the Farnborough and Sundridge reservoirs, which had involved restricting the supply to Bromley,

Bickley, Chislehurst and Shortlands by shutting down the mains at night. Further works were therefore approved by the Board in October, 1912. The first of these was the installation of duplicate machinery at the existing West Wickham well and the completion of a second well there and its connection by a heading to the first well.

The other works required statutory powers, which were subsequently embodied in the Metropolitan Water Board Act, 1913. These were a new pumping station near the old Shooter's Hill station which was to be abandoned; a service reservoir at Shooter's Hill to replace the Constitution Hill reservoir, which was supplied from Orpington ten miles away and which besides being in an unsatisfactory condition was too small for existing needs; a small reservoir adjoining that at Betsom's Hill; a new 10-inch main from the Westerham Hill station to this reservoir, and thence to Knockholt reservoir; and a small reservoir behind the pumping station at Westerham. The last two works were to remedy the complicated and wasteful system which existed at Westerham and Knockholt, where the water was pumped by two separate lifts and through about six miles of small mains.

The purchase of land on the Castlewood estate, Shooter's Hill, for a reservoir, and at Well Hall Road nearby, for a pumping station, was approved in 1914, and in November of the same year contracts were let for the construction of these works and of the reservoirs at Betsom's Hill and Westerham Hill. Their completion was, however, interrupted by the first World War.

The Board considered a further report on safeguarding the supply to the district in October, 1914. Since the Kent Company's undertaking had been transferred in 1904, the number of supplies had risen by about 13 per cent., and at a season when sources of supply were assumed to yield their minimum, the daily average supply to consumers was approaching 27½ million gallons, the figure adopted by the Balfour Commission as the ultimate yield of the area, and it was only possible to supply this amount by drawing on the reservoirs. In dealing with future supplies, the Chief Engineer also assumed a reliable output of 27½ million gallons a day from the

Kent wells, and intended to obtain whatever more was required from the Thames. The eastern and southern parts of the district were, however, at a considerable distance from London and were relatively high, and it was, therefore, considered that for these parts local supplies would be more economical. The Board possessed land for tapping additional sources at Sundridge and Bexley and they decided to sink wells at these two places and at Farningham or Eynsford. Only the well at Eynsford actually required statutory authority.

It was also resolved to seek statutory powers for constructing reservoirs at the following places: Eltham (3 million gallons); Bromley (5 million gallons); Farnborough (400,000 gallons); Hollard's Wood, Chelsfield (1 million gallons); and Bickley (1½ million gallons). These powers were included in the Metropolitan Water Board Act, 1915.

The war also prevented the execution of these works and it was not until September, 1919, that contracts were let for the construction of the Eltham and Farnborough reservoirs. In April, 1920, the Castlewood reservoir was completed. Tenders for the reservoirs at Bromley and Bickley and the pumping station buildings and machinery at West Wickham were accepted in January, May and October, 1921, and in the same year the Betsom's Hill, Westerham Hill, Eltham and Farnborough reservoirs were completed and brought into use. The works at Shortlands were completed in 1922.

The new pumping station at Well Hall Road was finished in July, 1922. It was the Board's first electric station, the original plant consisting of three electric motors driving centrifugal pumps and supplied with purchased electricity. In October, 1922, two vertical oil engines and well and surface pumps for the well then being sunk at Eynsford were ordered. It was hoped to obtain between 1.5 and 2 million gallons from this source.

In March, 1921, it had been decided to replace the original pumping plant of the Kent Company at Deptford, consisting of two old Boulton and Watt engines erected in 1811 and 1826. For this purpose two Worthington engines were to be transferred from the Board's pumping station at Molesey which had been abandoned. The construction of a new building to house these engines was started in 1922.

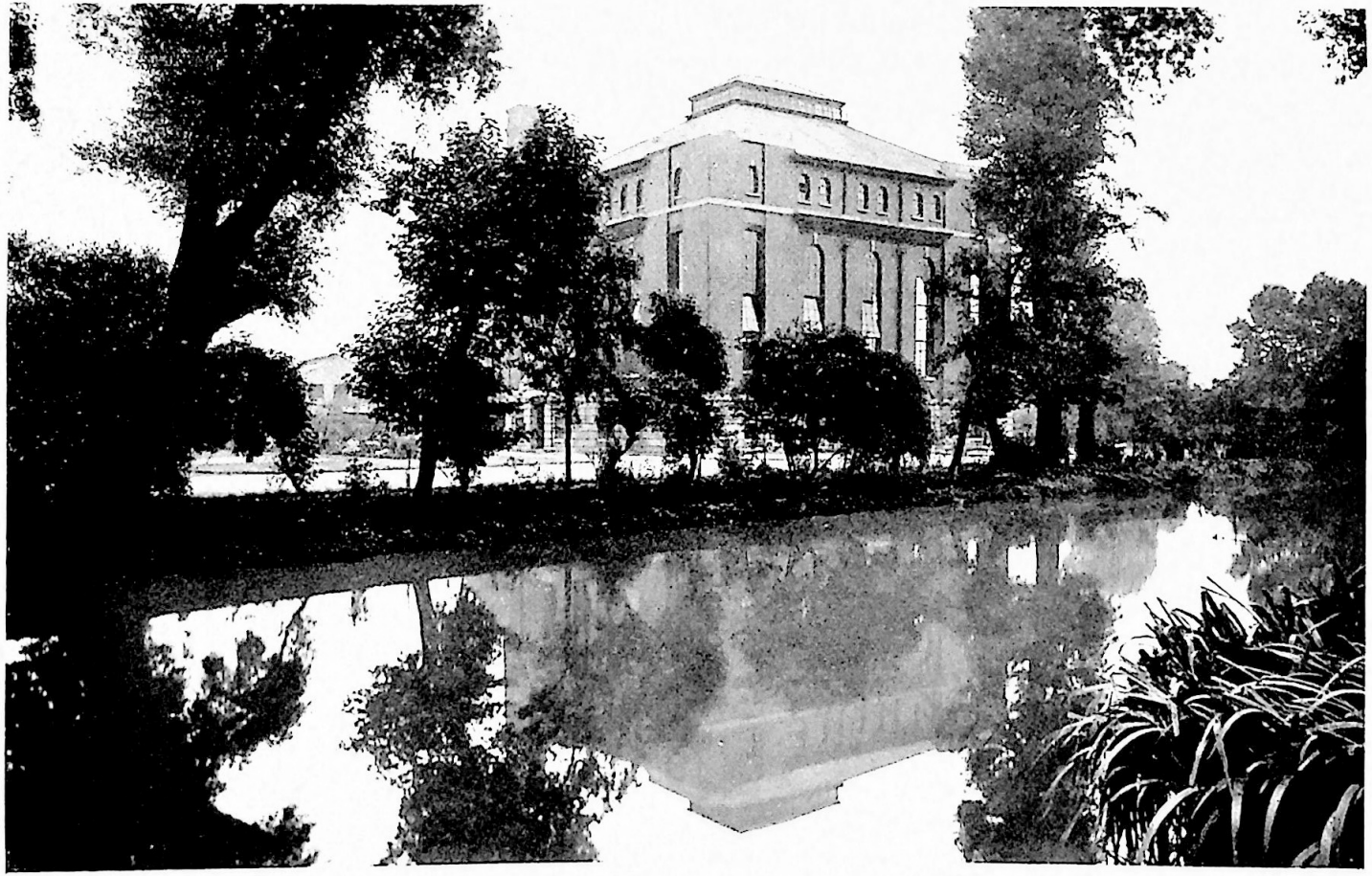
The reservoir at Bickley, of 1·5 million gallons capacity, was completed in February, 1923, and a contract for the construction of the Chelsfield reservoir was let in the following October. In the same year the new engine house at Deptford was finished and arrangements were made for the construction of an engine house for the new well at Eynsford.

On 19th July, 1923, the then Chairman of the Board, Mr. C. G. (later Sir Christopher) Musgrave, performed the ceremony of starting the new engines at the West Wickham pumping station. The pumping capacity of the station had now been increased from 1 million gallons to $3\frac{1}{4}$ million gallons per day. The machinery consisted of a triple expansion engine by Hathorn, Davey & Co., Ltd.

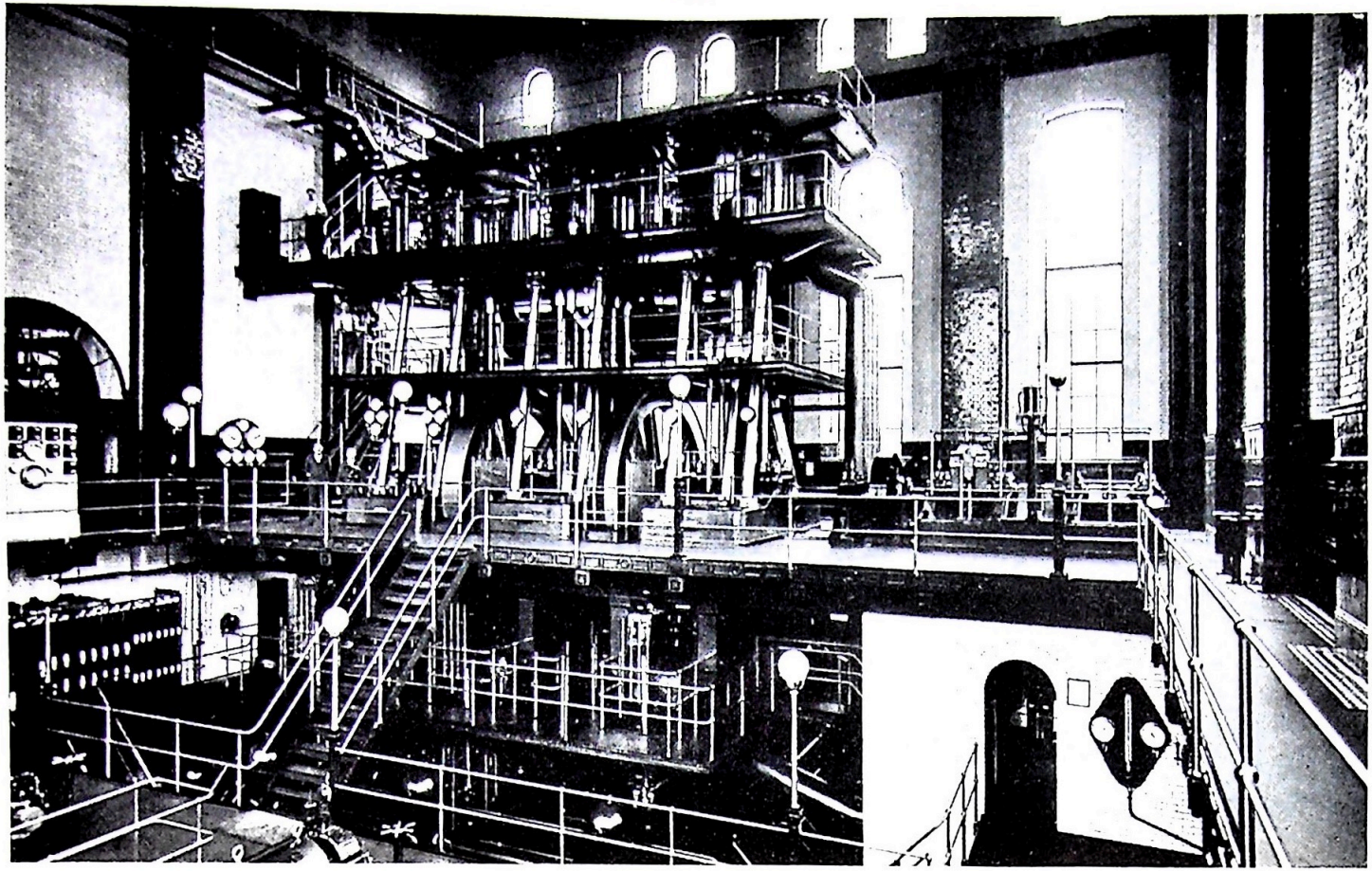
The Bromley and Chelsfield reservoirs were completed in July, 1924 and February, 1925.

On 23rd June, 1926, the Chairman of the Works and Stores Committee, Mr. R. W. James, inaugurated the new well station at Eynsford. The two oil engines at this station, by Ruston and Hornsby, Ltd., are capable of delivering 2 million gallons per day. The water from the well was intended to supplement the supply to the Knockholt zone, which had been provided from Orpington, Westerham Hill and Sundridge. This supply had been heavily taxed, and by bringing into use the Eynsford well the draught on the Orpington supply was greatly relieved.

In June, 1927, the Board had before them a report on the proposed remodelling of the Deptford works, the principal station of the Kent district. Similar proposals had been considered in 1921, but owing to the exceptionally high costs of machinery then prevailing it was not considered advisable to proceed with them. With the exception of the two Worthington engines recently mentioned the whole of the machinery, including six Cornish pumping engines, required early replacement, and the time was now considered suitable for completely reorganising the station so as to maintain the supply economically, and to provide for future developments. There were two sources of supply at the station—three wells in the chalk, and Thames water conveyed by a 24-inch main from Honor Oak. There were also two reservoirs of 1·75 million gallons capacity into which water from the well pumps and the 24-inch main



ENGINE HOUSE, DEPTFORD, 1932



THE TRIPLE EXPANSION ENGINE AT DEPTFORD

was discharged, whence it was delivered to the various service reservoirs.

The quantity of Thames water available for the Kent district had been increased by bringing into use the Walton to Honor Oak main in 1926 (see p. 127), and it was anticipated that in the future a greater supply of this water to the inner area of the Kent district would be required from Deptford, in order to permit the outlying wells, which were partly supplying the inner area to be more largely used in their immediate localities.

For this purpose it was proposed to install a triple expansion engine capable of pumping 7·2 million gallons a day from a new well to be connected to the three existing wells by adits, the remainder of the supply being Thames water. The pumps were to be capable of delivering as a maximum 8·3 million gallons a day to the low level district; 3 million gallons a day to the mid-level district; and 1·1 million gallons a day to the high level district. The concentration of all the units in one engine house would save labour and fuel. The proposed arrangement was also intended to combine the high efficiency and reliability of the reciprocating engine with the low cost of turbine standby. When the pumping station was in working order the whole of the old pumping machinery, with the exception of the Worthington engines, could be disposed of.

Since the remodelling would be effected while the station was kept in operation, the Board decided to sink the new well and drive the adits by direct administration as in the case of Eynsford and West Wickham.

Hathorn, Davey & Co., Ltd., were responsible for the main engine, Belliss & Morcom for the turbines and William Moss & Son, Ltd., built the engine and boiler house.

The inauguration of the new station was carried out on 15th June, 1932, when the new engines, which have a total horse-power of 1,550, were started by Mr. R. W. James, who had then become the Vice-Chairman of the Board. They were subsequently named "The James Engines."

The triple expansion engine drives four sets of pumps, including the well set which is driven from an extension of the crank shaft.

At the request of the Unemployment Grants Committee in 1929, the Board decided to co-operate in reducing the prevalent distress due to unemployment, and a number of works, which would not ordinarily have been put in hand, were submitted to the Unemployment Grants Committee and approved for the purpose of a grant from Exchequer funds. These works included a scheme approved by the Board on 18th July, 1930, for improving the supply to the Greenwich and Woolwich areas of the Kent district and the Dock area. The low level area south of the Thames which comprises portions of Deptford, Greenwich and Woolwich, was supplied at that time with water derived mostly from wells and pumped at the Deptford works. The scheme would enable this low lying area to be supplied almost entirely with Thames water transferred to Deptford, and make it possible to afford an additional supply in times of shortage to that part of the Northern district which lay immediately north of the Thames at north Woolwich. This could now be effected with the aid of the 48-inch Walton to Honor Oak main.

The scheme therefore consisted of laying a 30-inch pumping main from the Honor Oak pumping station to a point in Woolwich, where a connection could be made to the existing 20-inch Woolwich tunnel main. This latter main was connected to a tank at Plumstead with a top water level of 90 feet above O.D. The tank was ineffective, but by extending the main to a new reservoir with a top water level of 170 feet, water transferred to the Northern district at this point would be under the head of this reservoir, which would enable it to be delivered under suitable pressure. The Board already possessed sufficient land at Plumstead Common for a reservoir of about $1\frac{1}{3}$ million gallons, a quantity adequate for the purpose. The Government grant in this case took the form of a contribution of 100 per cent. of the interest, for a period of two years from the date of commencement, on any loans raised to meet approved expenditure thereon, and 50 per cent. of the interest after that date for the remainder of a period not exceeding 15 years in all in respect of each loan.

The construction of the reservoir was commenced in 1931, and finished in the following year. Its capacity is $1\frac{1}{2}$ million gallons.

In 1933, the Board's first automatic booster station was completed at Shoreham, the plant consisting of two automatically operated electrically driven centrifugal pumps. They raise the water to an additional head of 220 feet, and are automatically started and stopped when the pressure falls below or exceeds certain limits.

Increasing demands made it necessary for the Board in March, 1933, to duplicate the plant at the Sundridge well station, which entailed the sinking of a new borehole. This station draws its water from the lower greensand and the plant at that time consisted of a steam driven pump in the borehole delivering water to a Worthington engine, which in turn pumped into supply. This machinery was not new when installed in 1919, because of the high prices for new machinery. The Board decided, because of the development taking place, to have entirely new plant at this station and to remove the steam engines and pumps. In May, 1934, two vertical oil engines driving centrifugal pumps and electric generators were purchased, the latter supplying current for the electric motors driving the two borehole pumps. Each of the oil units had a pumping capacity of 1 million gallons per day against a head of 550 feet, the record head for the Board's area, and the two borehole pumps could each deliver 1 million gallons per day. The erection of the new plant and the sinking of the borehole were completed in 1935.

In July, 1934, the Board authorised the sinking, by direct labour, of another new borehole at the Green Street Green station and the provision of machinery, in order to keep up the supply to Southfleet reservoir in the event of a breakdown. The borehole and the building of a new engine house were completed in 1936. An oil engine with borehole and booster pumps and an electrical generator, with a pumping capacity of one million gallons a day, had been ordered and the new well was brought into use in August, 1937.

The Board's interim scheme for future supplies, which had been approved in October, 1934 (see p. 132), made provision for the laying of a 42-inch main from Hampton to Honor Oak and Nunhead reservoirs to meet the rapid building development in the area and to relieve the existing Southern district

trunk mains. It was expected that the new main would make it possible to satisfy the needs of the district for some years to come.

The remodelling of the Shortlands pumping station was decided upon in June, 1935. A partial scheme involving the installation here of machinery from another station had been outlined in 1931, but with further building development requiring 2 million gallons per day to be pumped from there to the Farnborough reservoir, it was considered more economical to instal new machinery for the purpose. This plant consisted of two oil engines with centrifugal pumps and generators supplying current to three electrical borehole pumps. Whilst the machinery was being constructed the Worthington engine, which had been removed from Sundridge pumping station, was used temporarily. The new machinery was completed and brought into use in November, 1937.

In 1935 the Kent area supply was derived from 24 wells and boreholes which were capable of yielding an average daily quantity of about 27 million gallons. To supplement this yield a gravitational supply of Thames water from the Honor Oak reservoir, introduced in 1917, had been increased in recent years by means of a pumped supply from the same works. On peak days the demand in the Kent district then exceeded 40 million gallons and on occasions it had exceeded 41.5 million gallons in one day, when just over 11 million gallons were supplied from the Thames.

Since April, 1932, outstanding development had taken place in the zones under the heads of the following reservoirs:

Woolwich Common, Eltham, Bromley	19,692	new	supplies
Castlewood	3,243	,,	,,
Bickley	6,483	,,	,,
Farnborough	7,568	,,	,,
	36,986	,,	,,

Whilst the percentage increase over the whole of the Board's area was 22.97, the corresponding figure for the Kent district was 56.46. To deal with the situation the following proposals were made:

To increase the area supplied with Thames water by extending the 24-inch Honor Oak main from Catford to Shortlands pumping station and by laying a main from Shortlands to connect with mains under the Farnborough reservoir head.

To replace the machinery at Orpington, consisting of two Cornish engines supplying water to the Farnborough, Castlewood, Southfleet and Bickley reservoirs and two small Worthington engines which boosted the water to West Wickham and Knockholt reservoirs. The new machinery to consist of four oil engines driving centrifugal pumps.

To install at Crayford four oil engines to replace an old horizontal engine and two rotative beam engines. Water from this well had been supplied to Woolwich Common reservoir and occasionally to Eltham reservoir.

These recommendations were adopted by the Board in November, 1935. In 1936 John Mowlem & Co., Ltd., undertook the necessary mainlaying. Tenders for the new machinery at Orpington and Crayford showed an increase in price of approximately 100 per cent. above that paid five years previously for a similar type of machinery. As no adequate financial gain could be expected from oil operated plant at this enhanced price, the Board decided to retain the existing steam engines and pumps for a further period and to replace the boilers at these works.

At the Board's request, a report on the subject of increasing or maintaining the yields from the existing wells and on possible sites for further wells or boreholes in the chalk or greensand, was prepared in 1935–36 by Professor P. G. H. Boswell, F.R.S. who expressed the opinion that by developing a number of the existing stations, and constructing certain new wells, about 10 million gallons of additional water might be obtained from the chalk. He urged caution, however, in the development of existing sites in the northern part of the Kent district owing to the possibility of contamination being caused by the influx of saline water from the Thames.

Further boreholes and one well have been constructed in the Kent area since 1938, to make the area as self-supporting as possible, and thus save the necessity and cost of pumping large

quantities of Thames-derived water into the district. Particulars will be found in the following table:

Boreholes constructed since 1938

(i) *Stations in use*

Site	*Number of Boreholes*	*Daily Yield (million gallons)*	*Date brought into use*
Bexley	2	5·0*	1940 and 1942
Eynsford	1	1·8	1943
Jewels Wood	1	0·1	1943
Darenth	1	2·0	1943
North Orpington	1	1·0	1946

(ii) *Stations not yet in use*

Site	*Number of Boreholes*	*Daily Yield (million gallons)*	*Date of sinking*
Brasted	2	1·0	1949 and 1952
Horton Kirby	2	2·0	1949 and 1951
Lullingstone	2	1·0	1949 and 1951

* This includes the yield of a well completed in 1950 and connected by headings to the boreholes at Bexley.

With all this activity in the construction of new boreholes, the Board had not overlooked the question of providing additional service reservoirs.

On the basis of an average daily supply of 300 million gallons, the Board's service reservoir capacity in 1944 amounted to two-thirds of a day's supply, but as the reservoirs were not situated uniformly over the whole area the relative capacity

was far less in many zones. To provide a reasonably safe margin of supply it was desirable that the Board should have not less than one day's supply in the service reservoirs controlling each zone. It was therefore proposed to increase the capacity of the service reservoirs in those zones where the need was greatest, by the construction of an additional 13 reservoirs, nine of which were to be in the Kent district. Statutory power to purchase the land required was obtained in the Board's 1946 Act.

Since the war, several remodelling and improvement schemes have been undertaken in the district, notably at Dartford; Shortlands; Ha Ha Road, Woolwich; Orpington; Crayford; and Wilmington.

In connection with the development of the underground resources in the Kent area, the Board decided in February, 1951, to sink five observation boreholes for the purpose of obtaining accurate and reliable records of variations in level of the underground water table. Suitable sites have been found for these between the valleys of the river Darent and the river Cray,but the Ministry of Housing and Local Government have not been able to authorise this work at present.

The Metropolitan Water Board Act of 1939 had empowered the Board to acquire land for the construction of a service reservoir at Knockholt, and in October, 1948, the Board decided that the work should be put in hand. As, however, the reservoir is to be larger than the one specified in the Act, a Ministerial Order under the Water Acts of 1945 and 1948, granting the necessary powers, was obtained. Government sanction to commence the work is still awaited.

CHAPTER XVI

The Major Remodelling Schemes

Hampton

THE works at Hampton, taken over by the Board in 1904, consisted of pumping machinery, reservoirs, filter beds and gravel beds, which had developed here during the previous fifty years with the expansion of the West Middlesex, the Grand Junction and the Southwark and Vauxhall Companies. The Hampton works of the West Middlesex Company were limited to abstracting water from the Thames and pumping the raw water to Barnes for filtration; those of the Grand Junction Company delivered both filtered and unfiltered water, the unfiltered water being pumped to their Kew Bridge works; and those of the Southwark and Vauxhall Company delivered the whole of that Company's filtered water. The supply areas of the West Middlesex and the Grand Junction Companies were on the north side of the Thames, whilst the Southwark and Vauxhall Company's area, as its name implies, was on the south side of the Thames. From Hampton, therefore, there was pumped both filtered and unfiltered water and the areas supplied were situated on both sides of the river. The pumping plant was accommodated in a number of engine houses erected at varying distances within about half a mile. The oldest machinery had been brought into use in 1855.

The first step in remodelling was taken in January, 1919. Some of the earliest Cornish "Bull" engines had been removed from the Grand Junction engine house and standby pumping plant was proposed to be erected in their place. Since the Board's then resources were being pressed to their utmost it was feared that a serious breakdown of machinery would result in the Board being unable to maintain an adequate supply. The provision of such plant had been considered by Mr. Restler during the war but it had not been possible at the time to effect the necessary alterations. Tenders were invited for

diesel engines and centrifugal pumps with a capacity of nine million gallons per day to act as standby for either the "Morelands" or the "Riverdale" engines which were the most powerful engines at Hampton. The "Morelands" were two compound engines, each of 530 horse power, and had a pumping capacity of nine million gallons per day. The "Riverdales" were three tri-compound engines, having a total of 1,590 horse power, and pumped filtered water to the Southern district. The tender of Hick, Hargreaves & Co., Ltd., was accepted for the diesel engines and pumps which were completed in 1922 and are known as the "Karslake" engines after the Chairman of the Board, Lt.-Col. J. B. P. Karslake. The taking over of these engines from the makers in December, 1922, coincided with a breakdown of one of the "Riverdale" engines. This resulted in a further examination of the other two "Riverdale" engines which were also found to require repair. No time was therefore lost before the "Karslake" engines entered on their duties.

A less important alteration was effected at the works in May, 1927, when the Board authorised the replacement of the "Sheffield" engines, two small low lift engines installed in 1885 and 1889 for pumping gravel water on to the filter beds. They were originally designed for an output of 16 million gallons per day each, but the water available for the previous 15 years had only averaged $3\frac{1}{2}$ million gallons a day. As 5 million gallons a day was considered the probable maximum required to be pumped, it was proposed to install electrically driven centrifugal pumps in duplicate, each capable of pumping that quantity. The plant at the works only generated current at 100 volts and it was decided to replace it by two steam-driven generators producing 200 volts. The electric pumps were ordered from Holden & Brooke, Ltd., in 1928, and the installation was completed in 1930.

There were still three Cornish "Bull" engines at the station. Two of these, then used in connection with an emergency supply for intercommunication pumping *via* the Battersea works, had been completed in 1855, the third, dating from 1864, being used for pumping unfiltered water on to certain high level filters. The working cost of these units was relatively high. In order to take advantage of the filtered and unfiltered

water wells of these engines, and of the limited space in the engine house, the Board decided in February, 1931, to install electric pumps supplied with current from a generator driven by an oil engine, the latter being housed in a vacant building nearby. The tender of Ruston & Hornsby, Ltd., for the generator and oil engine, with a capacity of 500 kilowatts, was accepted in November, 1931, four electric pumps being ordered from the Harland Engineering Co., Ltd., in the following month. Two of the pumps were to be used for raising unfiltered water to the high level filters, the third for pumping to the Nunhead reservoirs or to the Battersea works for intercommunication, and the fourth for pumping either to Kempton Park or to the Battersea works. The new engines, which were inaugurated on 31st May, 1933, were named the "Henry Ward" engines, after Mr. Henry Ward, J.P., an original member of the Board, who for many years had rendered distinguished services to the Metropolis.

In the meantime a general five-year programme providing for new works, machinery, mains, etc., had been considered. The estimates were of a preliminary character but served to indicate the scope of the work. The probable cost involved at Hampton was estimated at £680,000, which comprised the remodelling of the main pumping plant and the installation of primary filters.

Shortly before he retired Mr. Stilgoe presented a detailed report on the reconstruction of the Hampton works, and recommended that the work should be put in hand without delay. The report was examined in consultation with his successor, Lieut.-Colonel J. R. Davidson, and when it was submitted to the Board in February, 1934, it was emphasised that the remodelling of these works at an early date was necessary because of (*a*) the age of the existing plant, (*b*) the insufficient reserve capacity at peak load and for satisfying the increasing demands, and (*c*) economic considerations.

The station contained several engine houses each equipped with smaller and less efficient machinery than would have been the case had the station been constructed as one unit. With the exception of the "Karslake" and the "Henry Ward" engines, the plant was old and relatively uneconomical, having been installed prior to 1904. The boilers were now substantially

older than those used by commercial undertakings, and their continued use had only been possible by the manner in which they had been operated. The Board had recently arranged for the withdrawal from the Deptford, Surbiton, Hanworth Road and Brixton stations of 113 boilers from 42 to 82 years old. The trend of opinion was, and still is, to discourage the use of boilers over fifty years of age.

In estimating the increase in the supply the assumption had been made that for the next 30 years the increased demands of the Southern, Western and Kent districts would have to be met chiefly from the Hampton station. For this purpose it was proposed that the new installation should have a safe continuous output of at least 110 million gallons of filtered water a day as compared with the then maximum demand of 78 million gallons, this increase corresponding to the average rate of increase on the total quantity then supplied to those districts. Additional reserve units would, however, be available for exceptional demands.

As stations with large units are lower in capital charges per unit of capacity, more economical in coal consumption, and entail relatively less labour costs, it was desirable, when replacement of machinery was necessary, to consider concentrating as much of the plant in a single building as the safety of the supply and the overall economy permitted. This would avoid the difficulty, when using existing buildings, of ensuring the supply during the removal of old machinery piecemeal, constructing new foundations, altering buildings and erecting new plant. The policy of concentration had been adopted at the three stations recently reconstructed, *viz.*, Deptford, Surbiton and Brixton.

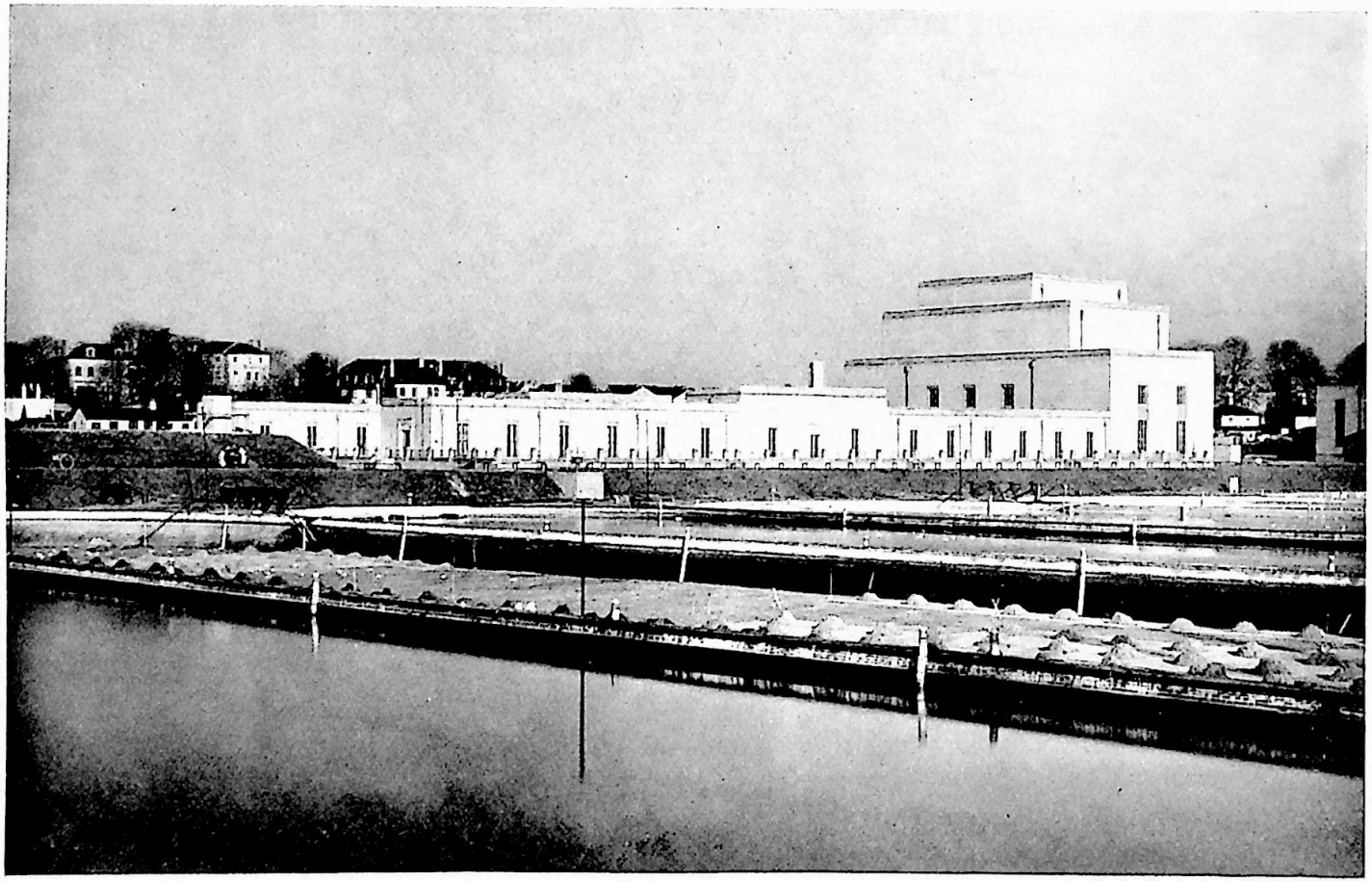
Surbiton and Brixton were not then completely in operation and comparative results were not available, but at Deptford (see p. 175) the working expenses had fallen from £20,347 in 1930–31 to £13,385 in the year ended March, 1933. Practically all the saving was attributable to the new plant whilst the pumping output was 3.2 million gallons a day more than previously. The saving was approximately the total amount required to pay the capital charges, i.e., not merely the amount actually chargeable to capital, but the whole of the interest

and repayments necessary to defray, during the expected life of the plant, the whole cost of construction.

Investigation had been made regarding the following four types of machinery:—(1) five steam turbines operating centrifugal pumps and two reciprocating engines, each with two sets of reciprocating pumps and each exhausting through a steam turbine operating centrifugal pumps; (2) twelve oil engines driving centrifugal pumps through gearing; (3) nine steam turbines driving, through gearing, centrifugal pumps; and (4) fourteen electrically driven centrifugal pumps operated by electric power purchased from the local electricity supply undertaking.

The four types were carefully examined from the standpoints of reliability and suitability and the conclusion was drawn that types (2) and (4) were unsuitable for the Board's purposes. Conditions of the oil industry at that period, the probable decline in the quantities available for import and the increased price for a home produced product, made any economic gain from the use of oil-driven plant of large capacity extremely speculative. The use of purchased electricity on such a scale would mean that the Board would have to rely entirely on an outside undertaking for the vital item of power, and in the case of failure the Board would have no control. Such a situation could not be justified even if there had been some economic advantage which, however, was not the case.

The choice, therefore, appeared to be between types (1) and (3). Type (1), which Mr. Stilgoe had favoured, possessed reliability in a very marked degree, breakdowns would be very exceptional and the plant could be relied upon to run for long continuous periods. On the other hand, type (3) also possessed a considerable degree of reliability and the plant could be installed and put into commission within three years as compared with four years for the reciprocating engines. A further important point was that the reciprocating engines in combination with steam turbines would be required to work for 40 years before the capital cost of the plant would be paid off, whereas the capital cost of the turbines operating centrifugal pumps would be discharged in 25 years. At the end of the latter period the Board would be in a position to take advantage of any improvements which might have developed. The saving



"THE DAVIDSON FILTER HOUSE," HAMPTON

INTERIOR OF THE DAVIDSON PRIMARY FILTER HOUSE

in capital cost, £130,000, would be substantial. In these circumstances, therefore, the steam turbine scheme, type (3), was recommended.

The machinery was to have a safe continuous output of at least 110 million gallons of filtered water and of 37 million gallons of unfiltered water per day. It was intended that the installation should include ample engine and boiler reserves to provide for the requirements of the next 25 years. The saving in the cost of coal, if pumping only the same quantity as the year before, would be about £16,700, and the total gross saving per annum in working expenses when pumping the future quantity, approximately £44,000 per annum, or a net saving after payment of the whole of the construction charges, of £25,500 per annum.

The total estimated cost of the proposed scheme, including machinery, coal-handling plant, buildings and working-out mains, but excluding certain filter and pumping mains, amounted to £365,000 as compared with the estimate of £480,000 contained in the five-year programme of 1931. These recommendations were adopted in February, 1934.

Consideration was now given to the filtration plant. It was first of all decided that the new purification plant should include a contact and balancing reservoir of 12 million gallons capacity, which would not only provide the contact period for complete chemical sterilisation, but would enable the load on the filter beds to be balanced between day and night and so ensure that they would be worked at a constant rate. The plan was to construct the tank at a higher level, and to raise the filtered water to it by low-lift electric pumps which would be worked from the generators working off the main high lift pumps. For this purpose the Board agreed in November, 1935, to increase the power of these engines sufficiently to meet the added load and to raise the output of filtered water at the station to 120 million gallons a day.

The Board had inherited from the old companies at Hampton, 5 intakes, 4 storage reservoirs with a capacity of 435 million gallons, and 40 filter beds, whilst 7 filter beds were added in 1906. In 1934, unfiltered water was being obtained from (*a*) Walton reservoirs (*b*) old intakes at Hampton (*c*) the

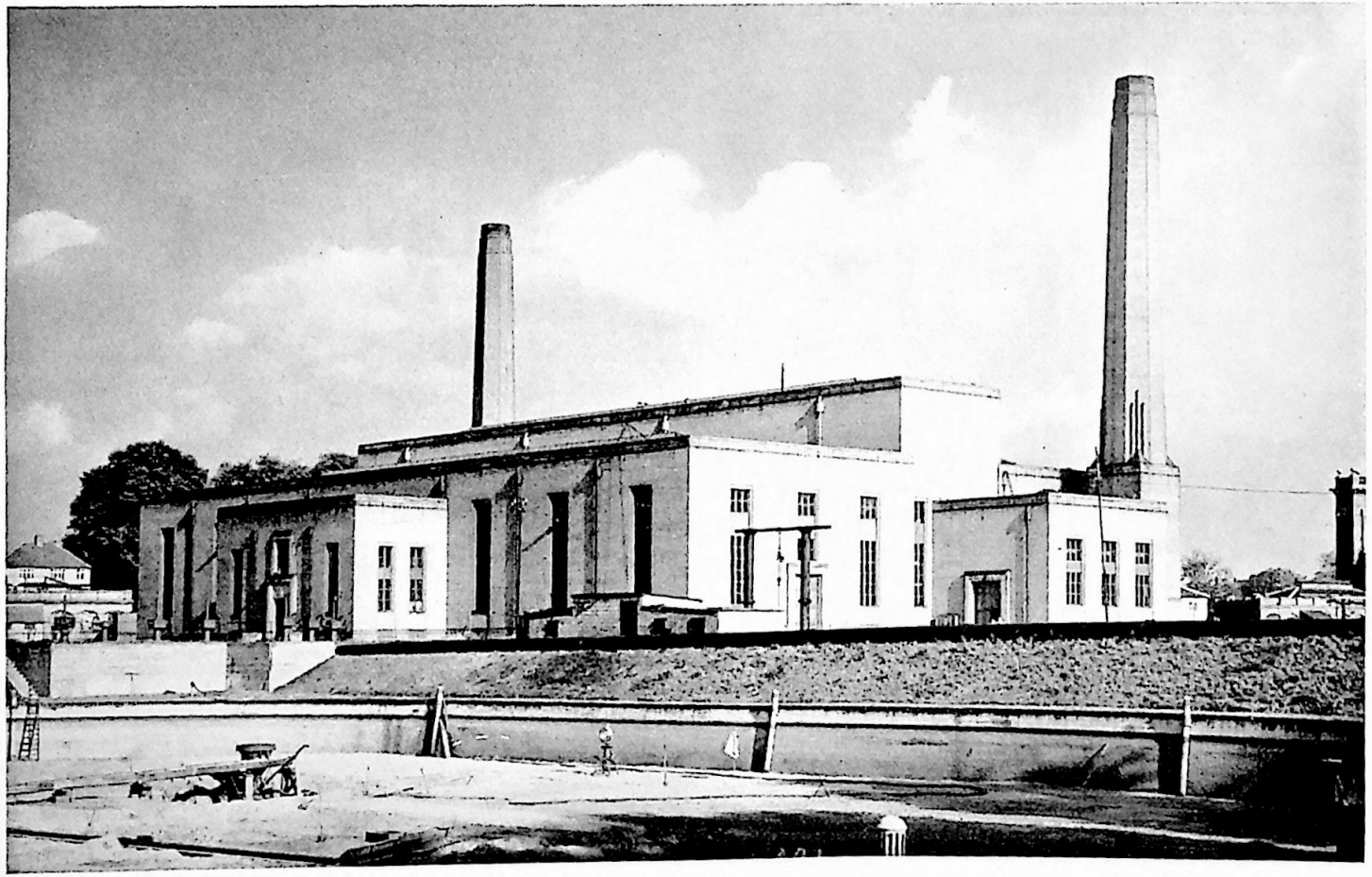
Queen Mary reservoir and (*d*) the Staines reservoirs and aqueduct. The sources were not interchangeable and the full quantity required could not be obtained from any one source. The filtration plant was only capable of dealing with about 65 million gallons a day and the trunk mains from Hampton were taxed to their full capacity during certain periods. A new 42-inch main, however, was to be laid to Honor Oak reservoir, and the Board's Act of 1935 had sanctioned the construction of a 60-inch main from Kempton Park to Cricklewood.

In February, 1936, the Board adopted the scheme for reorganising the filtration plant at Hampton and authorised expenditure of £940,250 for that purpose. The new works included the installation of 32 primary filters to operate in conjunction with the slow sand beds and so raise the normal capacity of the installation to about 120 million gallons a day. At the same time it was proposed that the number of slow sand beds should be reduced, the site of two being required for the new engine house and that of five others for the primary filters and the contact reservoir. In addition six further beds were also to be abandoned and part of the site used for a central sand-washing and wash-water disposal plant. The remaining 34 beds would suffice for an output of 120 million gallons. The low lift pumping plant would be housed in the primary filter house. It was also intended to bring back into use the two Stain Hill reservoirs which could be filled from the river at the "Sunnyside" part of the works.

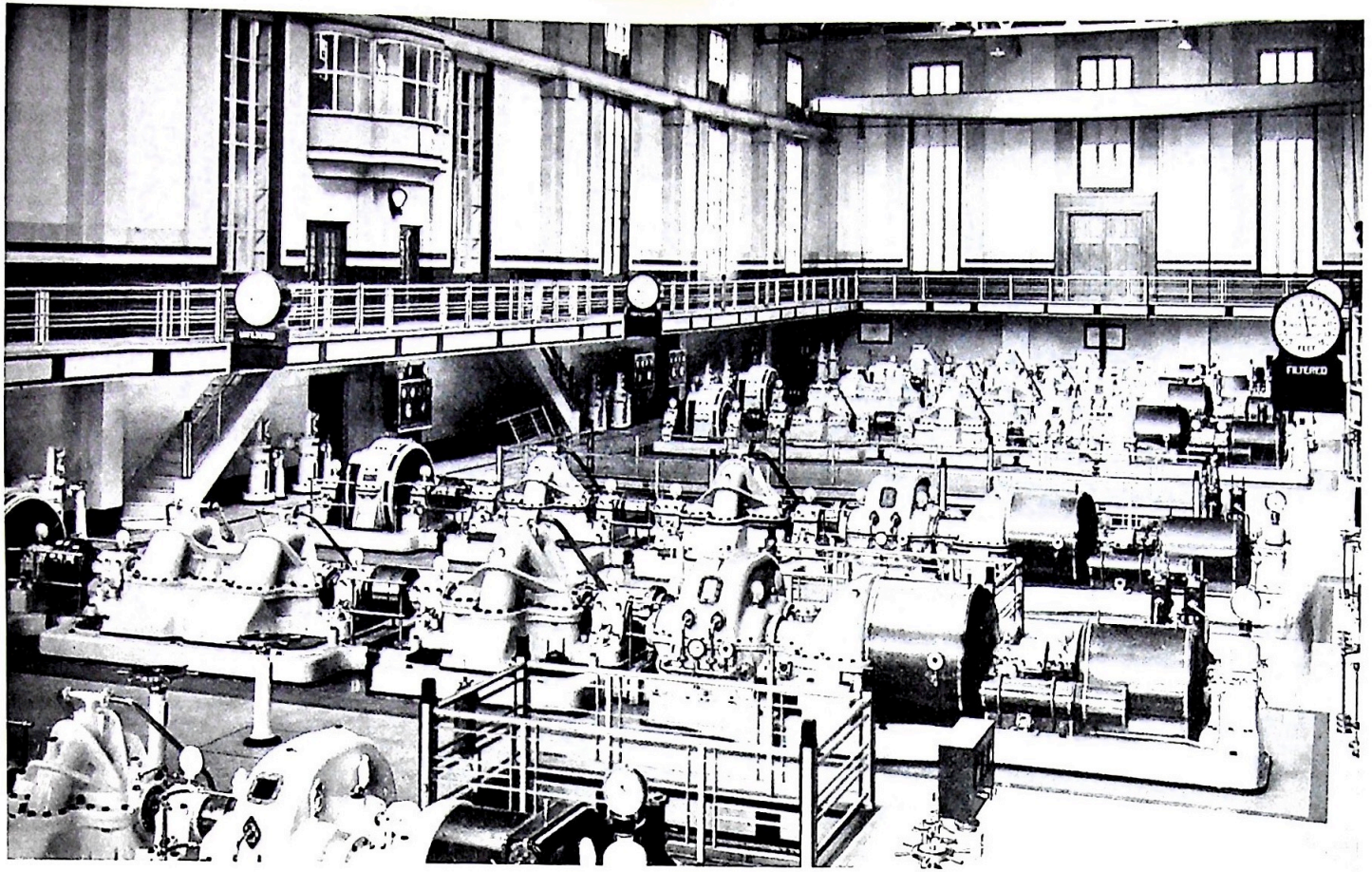
The United Filters and Engineering, Ltd., contracted for the apparatus for the primary filters in March, 1936.

In May, 1936, the tender of W. H. Allen, Sons & Co., Ltd., of £211,867, was accepted for the eight steam turbines with centrifugal pumps, seven of which were supplied with generators, one water turbine with centrifugal pumps and an electric generator, and one electric motor-driven unit with centrifugal pumps. Steam was to be provided by eight water-tube boilers for which the tender of John Thompson Water Tube Boilers, Ltd., was accepted in June, 1936.

Between the preparation of the estimates and the acceptance of the tenders for the steam turbines, main pumps and boilers,



"THE STILGOE ENGINE HOUSE," HAMPTON



"THE DURHAM ENGINES," HAMPTON

the prices of raw materials and finished products advanced considerably, due to improved trade conditions and increased wages. In addition, the Board had subsequently specified a greater steam pressure for the boilers and more powerful steam turbines necessitating an enlargement of the engine house. It had also been decided to place the conveyors for the coal and ashes in a tunnel connecting the pumping station to the coal wharf in order to protect the amenities of the district. These alterations made it necessary for the Board to sanction further expenditure in July, 1936, when the tender of William Moss & Sons, Ltd., was accepted for the construction of the engine house, etc. This new engine house, designed by the Board's architect, Mr. A. J. Johnson, F.R.I.B.A., and consisting of a steel frame structure, of an area of about 38,000 square feet, with two chimney shafts 146 feet high, was started in 1937.

In July, 1937, a tender from the same contractors was accepted for the construction of the primary filters, pump houses and control houses, chlorinating house and store buildings, etc., at £253,806, and in February, 1938, the low-lift pumping plant consisting of eleven electrically and two water turbine driven centrifugal pumps was ordered.

On 13th February, 1942, the Board decided to name the new engine house "The Stilgoe Engine House," the new filter house "The Davidson Filter House" and the high lift pumping machinery "The Durham Engines" after Mr. F. E. F. Durham, M.I.Mech.E., the Board's mechanical engineer at the time the plant was designed.

The contract for the primary filters and contingent works was officially completed in October, 1947, although some of them had been in use since 1941 and all the filters had been in commission since the latter half of 1945.

Although a contract for the contact and balancing reservoir had been entered into in July, 1939, work on it was interrupted for a long time by the war and it was not finally completed until April, 1949.

It was originally intended that power for pumping the raw Thames water from the Sunnyside intake to the Stain Hill reservoirs should be electric only, derived from the turbine-driven generators in the main engine house, but it was

decided in 1945 to use, when available, the head of the water passing from Walton and Stain Hill reservoirs to the "Grand Junction" reservoirs which fed the new primary filters. In October, 1945, therefore, the necessary machinery, including water turbines, etc., was ordered. A tender for the engine house at "Sunnyside" was accepted in 1946.

The long delay caused by the war and the consequent rise in prices resulted in the estimate approved for the augmentation of filtration capacity being substantially exceeded. By March, 1947, the estimated cost of the scheme had risen to £1,418,950.

In January, 1947, the Board considered the question of reconstructing the 29 "low-level" filter beds. Until further experience had been obtained and greater knowledge of the condition of the floor and underdrains of the beds became available, however, it was impracticable to give an accurate estimate of the cost, and the Board authorised, in the first instance, expenditure of £175,000. The work is being carried out by direct administration.

Surbiton

When the Board took over the undertakings of the metropolitan water companies in 1904, the works at Surbiton consisted of two adjacent filtration and pumping stations belonging to the Lambeth and Chelsea Waterworks Companies. The first instalment of the Lambeth Company's works at Surbiton was completed in 1852, and consisted of intakes feeding small filter beds and four compound beam engines pumping to Brixton reservoir. This company was the first of the water companies serving London to establish an intake above the tideway. The first part of the Chelsea Company's works was completed in 1856. The intakes of both companies were removed to Molesey in the 1870's.

The reconstruction of these two stations was considered in January, 1922. Both had been in need of reconstruction for a long time, but the work had had to be deferred on account of the war and the high cost of machinery. The majority of the engines in the Lambeth section had now reached such a condition that minor repairs were no longer sufficient to keep them in efficient order, and replacement would have to be undertaken if the supply was to be safely maintained. The

main pumping machinery of this section consisted of nine compound beam engines and a triple expansion Worthington engine, all pumping to the Brixton station, three of the beam engines also pumping to high level.

It was hoped that by 1925 the new filtration plant at Walton would be in operation (see page 126) which should to a certain extent relieve the engines at these works. This relief, however, would only be temporary, as pumping would have to resume gradually its original capacity as the demands on Walton itself increased. It was assumed that up to 10 million gallons per day could be made available at Walton for the relief of the Surbiton works.

The partial rebuilding of the four least efficient "Lambeth" engines would result in a net saving of £2,860 per annum. The alterations required, however, would have to be carried out before the water from Walton was available and until then it was scarcely possible to spare a single unit. The alternative suggestion, finally approved by the Board, was to install a steam turbine-driven pump having a capacity of 20 million gallons per day, and a 3 million gallons per day booster-pump, which could be installed with boilers in the house then occupied by the oldest boilers and in a new annexe thereto. The cost was estimated at £39,000, and the net saving at £4,800 per annum. With the completion of this unit further reconstruction either of the "Lambeth" or "Chelsea" sections could be deferred for a few years. The Board accepted the tender of C. A. Parsons & Co., Ltd., for the turbine and centrifugal pumps, the installation of which was completed in 1925.

The complete remodelling of the station was considered by the Board in 1929.

The "Chelsea" engines consisted mainly of eight compound beam engines, the first four of which had been erected in 1856. These engines pumped to the reservoirs on Putney Heath.

The original scheme providing for the concentration of the necessary machinery in one house envisaged a site mid-way between the two old stations, but on developing the plan it was found practicable and more economical to remodel the original "Lambeth" engine and boiler houses for the reception of the plant.

The most suitable plant to replace the remaining "Lambeth" engines and all the "Chelsea" engines was found to be four steam turbines driving centrifugal pumps and boosters, and three water-tube boilers.

Provision was to be made for a normal output of 45 million gallons a day and a maximum output of 60 million gallons a day. The auxiliary machinery would be replaced by water turbine and electrically driven centrifugal pumps, electricity being supplied from generators operated by two of the main pumping units.

Consideration was given to the question of constructing primary filters, but this would have entailed very heavy cost for providing the necessary supply mains. The possibility of constructing these at a future date was, however, kept in mind.

Before the Walton filtration plant was installed, the Surbiton output varied from an average of 45 to a maximum of 55 million gallons per day. Now that Walton had taken up a portion of the Surbiton duty, the average was 35 million gallons a day, but the maximum was the same. The estimated saving after repayment of capital charges amounted to £4,000 per annum, but on the low price of coal then obtaining the saving in working expenses would approximately balance capital charges.

The scheme, estimated to cost £220,000, was approved by the Board in July, 1929. In July, 1930, the reconstruction of the engine and boiler houses and other works was put in hand. Worthington-Simpson, Ltd., supplied the four steam turbines with centrifugal pumps and two electric generators.

The Minister of Health, the Rt. Hon. Sir Hilton Young, G.B.E., D.S.O., D.S.C., M.P. (now Lord Kennet), inaugurated the works on 1st November, 1932, when the engines were named "The Sir George and Lady Handover Engines," after the Chairman of the Works and Stores Committee and his wife.

Certain auxiliary plant, consisting of low-lift pumps, was subsequently installed by Worthington-Simpson, Ltd., and the new works were finally completed in January, 1934.

In May, 1952, the Board approved a scheme providing for the construction of a two million gallon contact tank at the

station. This is to ensure that the water will be in contact with the chlorine for half an hour before leaving the works, when the output from the station is at the rate of 45 million gallons a day.

Low lift pumping plant driven by purchased electricity will be installed for delivering water to the tank and diesel generators are to be used for standby purposes. The steam turbine, completed in 1925 and now only used as a standby, will be scrapped. Automatic chemical dosing plant will also be provided. The total cost of the scheme is estimated at £240,600.

Brixton

These works, which formerly belonged to the Lambeth Waterworks Company, receive filtered water from Surbiton and Walton. By 1930, an average of 20 million gallons a day was pumped from Surbiton, a large part of which was supplied *en route* into the district, the remainder being delivered into the Brixton reservoirs. From Walton about 22 million gallons a day on an average were pumped through the new main, which was 48 inches in diameter between Walton and Brixton and 36 inches between Brixton and Honor Oak (see page 126). Just before the main reached Brixton there was a 30-inch branch main through which water was supplied into the district, and at the point where the 48-inch main was reduced to 36 inches there was a connection to the Brixton reservoirs.

The total quantity received from Surbiton and Walton varied, but could be assumed to be about 29 m.g.d., an average of about 9 m.g.d. being pumped to various reservoirs and the remainder, about 20 million gallons, gravitating northwards through five trunk mains. There was also a 30-inch main for conveying water from Brixton to the Battersea works. The maximum quantity pumped from Brixton at that time was about 11 million gallons in one day.

There were at Brixton in 1930, three engine and boiler houses, housing nine engines and 17 boilers, together with stores and offices. In considering the remodelling of the station it was necessary, in the interests of efficiency and economy, to concentrate the new machinery in one building. One of the existing engine houses had been considered for the purpose, but this was found to be impracticable as none of the pumping

units could be dispensed with until new machinery had been installed. A site previously occupied by a stable block and foremen's offices, etc., was therefore chosen for the new engine house as this would entail the least cost in building and alterations.

The engines at Brixton pumped to reservoirs at Norwood, Forest Hill, Selhurst, Streatham Hill, Rock Hill and the Crystal Palace tank. The supply to Norwood was to be pumped direct from Surbiton, but it was proposed to arrange the new machinery at Brixton so that, should a breakdown occur either at Surbiton or in the 30-inch main to Brixton, it would be possible to maintain the supply.

After considering the different types of machinery available and the various levels to which the water had to be pumped, which levels it was now intended to group mainly into two pressures of 200 feet and 400 feet, a scheme for installing six oil engines, each driving two centrifugal pumps, was selected. As the units would be identical in design and interchangeable, it would be possible to provide adequate standby power for such conditions as could then be foreseen. Space would be provided in the engine house for an additional unit.

The estimated annual saving when performing the same amount of work as the existing station, including pumping to Norwood, would be about £5,000. With the pumping to Norwood carried out from Surbiton, the saving would be £1,000 per annum after payment of capital charges.

The above scheme was approved by the Board in December, 1930.

In November, 1931, the Board accepted the tender of W. H. Allen, Sons & Co., Ltd., for the six oil engines and centrifugal pumps, and in January, 1932, decided to place the construction of the new engine house and other works in the hands of Mr. J. McKenzie of Hendon. The foundation stone of the new building was laid by Sir George Handover on 12th July, 1932. The engine house and the oil engines were brought into use in June, 1933.

Following the abnormally hot summer of 1933, the supply to the Norwood zone had still to be repumped from the Brixton station. The 48-inch pumping main from Walton to Honor Oak (see p. 126) passed close to the Brixton works and, as a

part of the remodelling scheme, a connection was made from the pumps at Brixton to this main to enable water from Surbiton to be repumped from Brixton to Honor Oak in emergency. This latter reservoir was becoming increasingly important as it not only supplied the Southern district and Deptford by gravity, but also Bromley, by pumping, if required. Water from Honor Oak was also pumped directly into the Northern district *via* the Woolwich subway and to the Nunhead reservoirs, to enable water to be sent under the Thames through the Tower subway to east London.

While there was no intention to abandon the scheme of pumping direct from Surbiton to the Norwood zone, it was felt that it might not be possible to bring the system into operation for some time, and a seventh engine at Brixton became necessary to provide adequate reserve to pump to Honor Oak if required.

The engine, which was provided by W. H. Allen, Sons & Co., Ltd., was brought into use in June, 1934.

Lee Bridge

The Lee Bridge station, the second largest taken over by the Board, had been the principal distribution centre of the East London Water Works Company. The main pumping machinery consisted of Cornish engines, compound engines, triple expansion engines and water turbines, with a total capacity of 103 million gallons a day.

Increasing demands in the zone served by the Woodford reservoir made it necessary to provide additional pumping plant at the Lee Bridge works, and in July, 1921, the Board decided to purchase a triple expansion engine from Hathorn, Davey & Co., Ltd. This was erected in a reconstructed engine house which had previously accommodated machinery pumping from a well. In May, 1925, the Chairman of the Board (Sir Christopher Musgrave) performed the ceremony of starting the engine, which was named after him. The engine has a total capacity of 14 million gallons a day when pumping to Woodford reservoir.

Early in 1941 the Board decided that the reconstruction of the works should receive prior consideration after the war,

but in 1942 they considered it advisable to replace without delay the engines serving the "Triples" zone, an area which extended from eastern Hackney, Bethnal Green and Stepney to Barking Creek. The engines concerned were the "Triples" (three triple expansion engines) the "Prince Consort" (another triple expansion engine) and the "Victoria" (a 100-inch cylinder Cornish engine erected in 1854 and the oldest permanent engine at the works). The new machinery, which was installed in 1943, consisted of electric pumping sets made by Worthington-Simpson Ltd., estimated to save running costs of £14,000 per annum. In 1943 the Board took the opportunity of buying two partly manufactured electric centrifugal pumps and erected these at Lee Bridge to replace the "Connaught" engine (a horizontal triple expansion Worthington). The only engines of the East London Waterworks left in regular use were the "Prince" and "Princess," two Cornish engines pumping to the Finsbury Park reservoir, and the "Duke" and "Duchess," two compound rotative engines pumping to the Woodford reservoir.

On account of the age of the filter beds and the layout of the conduits at the station, which give rise to difficulty in treating the water effectively, it is intended ultimately to shut down the present works and to establish a new station at Copper Mills, Walthamstow. In the meantime, however, it has been necessary to undertake a partial remodelling. The scheme, which was approved by the Board in 1945, involved the provision of low-lift pumps to lift filtered water from the existing conduits into a contact tank, which is divided into two parts so that each part can be used separately if necessary. At the entrance to the tank the water passes through screens to eliminate suspended matter. For the high-lift plant, eleven electric pumps (including five of the existing ones) have been set up in a new building adjacent to the contact tank.

Current is provided by the grid, and to ensure against failure standby generating plant was installed, consisting of twelve oil-driven generators already held by the Board.

As a result of this scheme eight engines, nineteen boilers and five buildings have become redundant.

Between February and July, 1946, the Board decided to buy eight electric low-lift pumps from Hathorn, Davey & Co., Ltd.,

and six motors from the Harland Engineering Co., Ltd., to drive six existing pumps. Arrangements were also made with Leyton Borough Council for the duplication of the electricity supply main, and the tender of Braithwaite & Co. (Engineers), Ltd., was accepted for the construction of a steel contact tank.

Owing to the greater incidence of algal growths, increasing difficulty was experienced in maintaining the proper output from the filter beds, and in order to improve the position it was decided in December, 1948, to set up ten rotary strainers, each ten feet in diameter and ten feet long, arranged in five reinforced concrete chambers and housed in a building on the east bank of the Lee Bridge aqueduct. In April, 1949, the tender of Glenfield & Kennedy, Ltd., at £61,065, was accepted for the provision of these strainers.

The contact tank was brought into use in April, 1949.

The diesel generators were found to be incapable of running for long periods under full load, and to strengthen the generation of electricity it was decided, in October, 1951, to transfer a diesel engine and alternator, intended for the Ashford Common works, to Lee Bridge as standby and peak load relief. The installation of this machinery was completed in November, 1952. The engine is the largest of its type in use by the Board. It is of 1,700 horse power and the alternator produces 1,100 kilowatts at 3,300 volts.

Work under the remodelling scheme is now substantially complete.

Hammersmith

Mention should also be made of Hammersmith pumping station which distributes the water filtered at the Barnes and Barn Elms filtration works. Hammersmith has undergone a gradual reorganisation ever since the early days of the Board, but still retains some old steam pumping plant including a pair of compound beam engines which although over 70 years old are still available for duty. The machinery installed by the Board includes two triple expansion engines erected in 1910; a steam turbine driving centrifugal pumps and a generator, dating from 1936; two electric pumps erected in 1938, both of which obtain power from the generator but can

also be operated by purchased electricity; and two further electric pumps brought into use in 1946.

In April, 1948, an interim scheme was approved, involving the scrapping of one of the old compound beam engines, and the installation of electric pumps with a total capacity of 30 million gallons a day. Four diesel alternators for standby and peak load relief are also included in the scheme.

Reference to the remodelling of the Deptford and Stoke Newington stations will be found at pages 174 and 221.

Construction of new works and reconstruction of existing works

The Chief Engineer in January, 1946, submitted to the Works and Stores Committee a programme for the construction of new works and the reconstruction of existing works which should be carried out during the following fifteen years, in order to maintain an adequate supply of water. The programme was adopted as a general basis for the Chief Engineer's guidance in the preparation of schemes, subject to such variations as might from time to time be found desirable to meet changing circumstances. The total expenditure was estimated at the time at £37,262,000, but separate estimates would have to be submitted in respect of the individual projects. The programme is of a comprehensive nature and includes works already in hand or previously authorised, the most important of which have been described in previous pages.

CHAPTER XVII

Matters concerning Distribution

Waste

EVERY water undertaking in this country is of necessity concerned with the prevention and suppression of waste of water. The Board's history provides a record of steady progress in this field.

Waste of water cannot be entirely prevented as pipes and fittings have a limited life and eventually fail, but much can be done by the use of the most suitable materials and the adoption of the soundest methods of design and practice. Reference is made later to the problem of maintaining the system of mains and to the control exercised through the operation of byelaws.

Suppression of waste is a matter calling for considerable organisation and constant vigilance. A dripping tap may waste a few gallons of water in an hour, a broken lead pipe several hundred and a broken main thousands of gallons, but the problem concerns hundreds of thousands of fresh defects which occur every year, the leakage from which, if not stopped within a reasonable time, could seriously affect the Board's ability to provide a sufficient supply.

The first step in the suppression of waste is its detection, which presents an obvious difficulty since so much of it occurs within premises or underground. Fortunately this difficulty can be overcome by means of the Deacon waste water meter system.

The Waste Water Meter System

The Deacon waste water meter system was devised towards the end of the last century by Mr. G. F. Deacon of the Liverpool Corporation Waterworks. It involves the division of the area into small waste districts, each of which can be separately supplied with water through a single recording meter known as a waste meter. It is thus possible to select any waste district and, by the manipulation of valves, to measure all the water

flowing into it, and the rate of flow at different times of the day or night.

Deacon waste meters have been operated in parts of the Board's area for many years. They were installed by certain of the old companies and their number has progressively increased during the past fifty years. A special sub-Committee of the Works and Stores Committee which, in 1926, thoroughly investigated their utility, expressed the view that there should be no relaxation of effort in controlling consumption by the installation of waste meters and in the provision of the requisite staff. The work was hindered somewhat by economic and other difficulties, but by 1939 about 80 per cent. of all supplies could be controlled by this means.

Waste suppression experienced a setback during the war years. When the war ended it was clear that because of the restriction on the construction of new works during the preceding six years, the Board might have difficulty in meeting the increasing legitimate demand for water, unless the increase could be offset by a substantial reduction of the quantity of water lost by leakage and waste. Accordingly, in 1946, the Board re-affirmed the policy of completing the waste-metering of the whole area without delay, and steady progress has been made since that date. Since the end of the war expenditure on suppression of waste, chiefly by the extension and improvement of the waste meter system, has amounted to £130,000.

In 1939, there were 2,124 districts which were controlled by 1,629 waste water meters. The difference between the number of districts and the number of meters is explained by the fact that it is sometimes possible to arrange the connections to a meter in such a way that it can control more than one district, though not at the same time, and that is, of course, an economy.

By the end of March, 1952, there were 2,971 districts which were controlled by 1,824 waste water meters, the supplies controlled by meters having risen from 80 to over 90 per cent.

The waste water meters are not run continuously but each is put into operation for 12 to 18 hours at intervals of approximately two months. A meter is usually started in the late after-

noon or early evening, and the chart is removed on the following morning. This operation is known as an "open reading," and particular attention is paid to the recorded rate of flow during the early hours of the morning, when legitimate consumption is usually at its lowest. The minimum night flow recorded by the meter thus gives a good indication, though not an actual measurement, of the amount of water which is being lost through leakage, etc., from the mains, pipes or fittings in a particular waste district. By comparing this minimum night flow with that which is known from experience to be reasonable, it is possible to estimate quickly whether undue waste is taking place. If the chart from an open reading indicates that there may be undue waste or leakage on a particular waste district, the waste can usually be located within narrow limits by what is termed a "valve inspection." To make such an inspection, the waste water meter is run during the early hours of the morning, each main being shut down in turn at a pre-arranged time. If, when the meter chart is examined, it is found that the shutting down of a particular main has resulted in a marked drop in the rate of flow through the meter, there is *prima facie* evidence of leakage or waste from that main or the pipes connected with it. Valve inspections are made at night in order to cause the minimum inconvenience to consumers and because legitimate use is then at its lowest.

During the year ended 31st March, 1952, there were 1,438 valve inspections as a result of which waste at the rate of 14.1 million gallons a day was discovered and stopped. Other inspections made in conjunction with the waste meters accounted for 7.6 million gallons a day making a total of 21.7 million gallons a day.

The evidence provided by the "valve inspection" chart is used by the inspection staff in tracing the leakages causing waste. Detailed investigation is carried out by inspectors who employ special stethoscopes, or sounding sticks, to detect the sound of running water. By this means leakages from mains and pipes in the street, and in premises containing defective fittings, can be found. It is of interest to note that during the year ended 31st March, 1952, 18,854 defects were located by the inspection staff on the Board's system and 160,996 on consumers' installations.

Whilst many consumers readily take steps to repair defective fittings there are others who need to be pressed to do so, and a considerable staff is employed on correspondence to that end. The Board have the power to withdraw supplies for the failure to repair defective fittings, but this rarely has to be exercised.

In much of the Board's area there is an appreciable legitimate consumption of water during the night at such premises as factories, large hotels, gas works, etc. In addition, the refilling of storage cisterns may go on throughout the night if the cisterns are large and the service pipes small. The minimum night flow recorded by a waste water meter does not, therefore, always solely represent water which is wasted or lost through leakage. On the other hand, it can be a good indicator of leakage or waste, inasmuch as a sudden rise above what experience has shown to be normal would be *prima facie* evidence of waste.

The following table gives a comparison between the minimum night flow as recorded by the Deacon meters and the average daily consumption:

Year.	Deacon Meters.		Average daily supply.	Difference.
	Average minimum night flow.	Difference.		
	m.g.	m.g.	m.g.	m.g.
1946–47	80·5		325·5	
		+5·3		+8·3
1947–48	85·8		333·8	
		—9·6		—10·1
1948–49	76·2		323·7	
		—9·0		—7·8
1949–50	67·2		315·9	
		—2·7		—2·9
1950–51	64·5		313·0	
		—0·2		+3·3
1951–52	64·3		316·3	

Although it is not suggested that the drop in the average daily consumption is due solely to the suppression of waste, the similarity between the figures is noteworthy.

In order to obtain some information about the quantities of water flowing in the distribution system at different times of the day and night, a test was made in May, 1949, during which the night flow was measured at hourly intervals over four consecutive days. The minimum night flow recorded for the whole of the Board's area (trunk and service mains) was estimated at the rate of 142 million gallons a day. The test was repeated under identical conditions in May, 1950, when the minimum night flow recorded was 119 million gallons a day or 23 million gallons less. These figures confirm the effectiveness of the system for detecting and preventing waste.

Briefly, the suppression of waste is important for the following reasons:

(*a*) It helps to keep down operating costs, particularly where all water has to be treated and pumped, as in the Board's area.

(*b*) It enables the construction of new capital works to be deferred.

(*c*) It facilitates the meeting of abnormally high demands for water, such as occur during very hot weather.

In order to be successful, waste detection and suppression must be continuous. The problem is made more difficult in the Board's area because of the relatively high legitimate night consumption of water but the results so far achieved show clearly that much can be done to keep losses from leakage, etc., within reasonable limits. As the installation of meters proceeds, further success in waste prevention is expected.

The routine work of waste detection is carried out by the inspection staff consisting of foremen of inspections and inspectors. There are 32 foremen of inspections, each in charge of a district and having under his control an average of ten inspectors. Special investigations are undertaken to trace the cause of leakages entering basements, railway tunnels, sewers and cable ducts. These operations often call for extensive sounding tests usually carried out after midnight when traffic conditions are most favourable.

Water Regulations

Under the provisions of the Metropolis Water Act, 1871, the companies were required to make regulations, subject to confirmation by the Board of Trade, for the purpose of preventing the waste or misuse of water. These regulations might prescribe the size, nature and strength of the pipes, cocks, cisterns, etc., to be used and might prohibit the use of any apparatus which might tend to the waste or misuse of water. Regulations were duly made by the companies and confirmed by the Board of Trade in the year 1872.

Fresh powers were obtained by the Board's Act of 1932, to make byelaws for the purpose of preventing waste, undue consumption, misuse or contamination of water, including byelaws requiring the testing and stamping of fittings. The Act provided that the regulations under the 1871 Act were to continue in force until 1st January, 1935, or the date of the coming into force of any byelaws made under the Board's Act of 1932, whichever should first occur.

After conferences with other bodies, and the examination of the model byelaws issued by the Ministry of Health in 1928, draft byelaws were adopted by the Board on 13th July, 1934. Certain of these were confirmed by the Minister of Health on 31st December, 1934, and the remainder on 4th February, 1935, and were, by the Minister's certificates, to remain in force for a period not exceeding ten years from the date of confirmation.

Owing to wartime conditions, certain materials became scarce, and modifications in a number of byelaws were, therefore, made by the Board and confirmed by the Minister in December, 1944. The period of duration of the byelaws was extended for three years to 31st December, 1947, and subsequently to October, 1950.

After the revision of the Model Byelaws by the Ministry in 1949, the Board made new byelaws in 1950 under section 16 of their 1932 Act, and these were confirmed on 14th September, 1950.

In July, 1951, the Board's observations were invited on a draft Order which the Ministry of Local Government and Planning (now the Ministry of Housing and Local Govern-

ment) would be prepared to make under the provisions of the Water Act, 1945, and which would extend the Board's existing byelaws to 30th July, 1960.

The effect of this draft Order appeared to be that the Board would in future have no alternative but to make byelaws under the Water Act, except in a few limited cases. It would also repeal provisions in the Board's special Acts under which the Board have power to withdraw supplies in default of compliance with their byelaws.

In view of the short time remaining before the byelaws expired, the Board requested the Minister to extend their operation for a period of at least 6 months, to enable negotiations to take place on the terms of the draft Order. Extensions of time until 31st March, 1952, and later, to 31st March, 1953, were duly granted by Orders.

The Minister subsequently agreed that the Board's powers to cut off water, on account of waste or non-compliance with byelaws, should not be repealed for the time being. On this understanding the Board decided, in December, 1952, to make application to the Minister for an Order under the Water Act, repealing the Board's powers for making byelaws, excepting those relating to the testing and stamping of fittings, and continuing in force the existing byelaws until July, 1960.

Fracture of Water Mains

Serious gas explosions which occurred in High Holborn in December, 1928, and a succession of fractures in water mains which occurred in the early part of 1929, attracted considerable notice in the public press. The bursts were attributable to various causes, but the number was not excessive, nor indeed above the average occurring in the winter months.

In March, 1929, a special sub-Committee was appointed to investigate the whole subject. Their report was submitted to the Board in December, 1930. This report showed that so far as the Metropolis was concerned there was no reason to regard the number of fractured mains as an abnormal feature of London's water supply. Indeed, the contrary was the case when regard was had to the extensive mileage of the Board's mains.

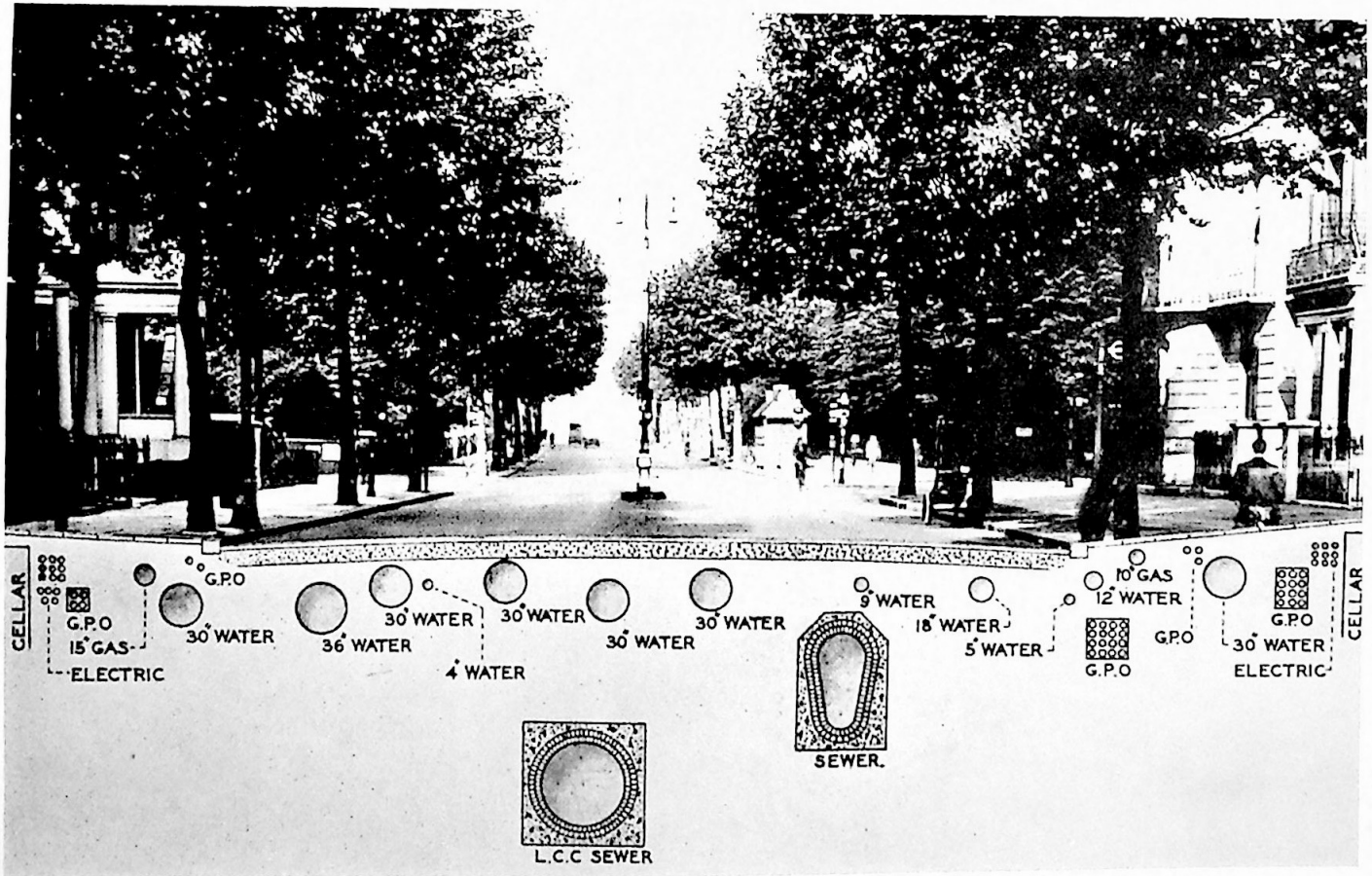
The relative merits of cast iron and steel were also investigated

by the sub-Committee, who reached the following conclusions:

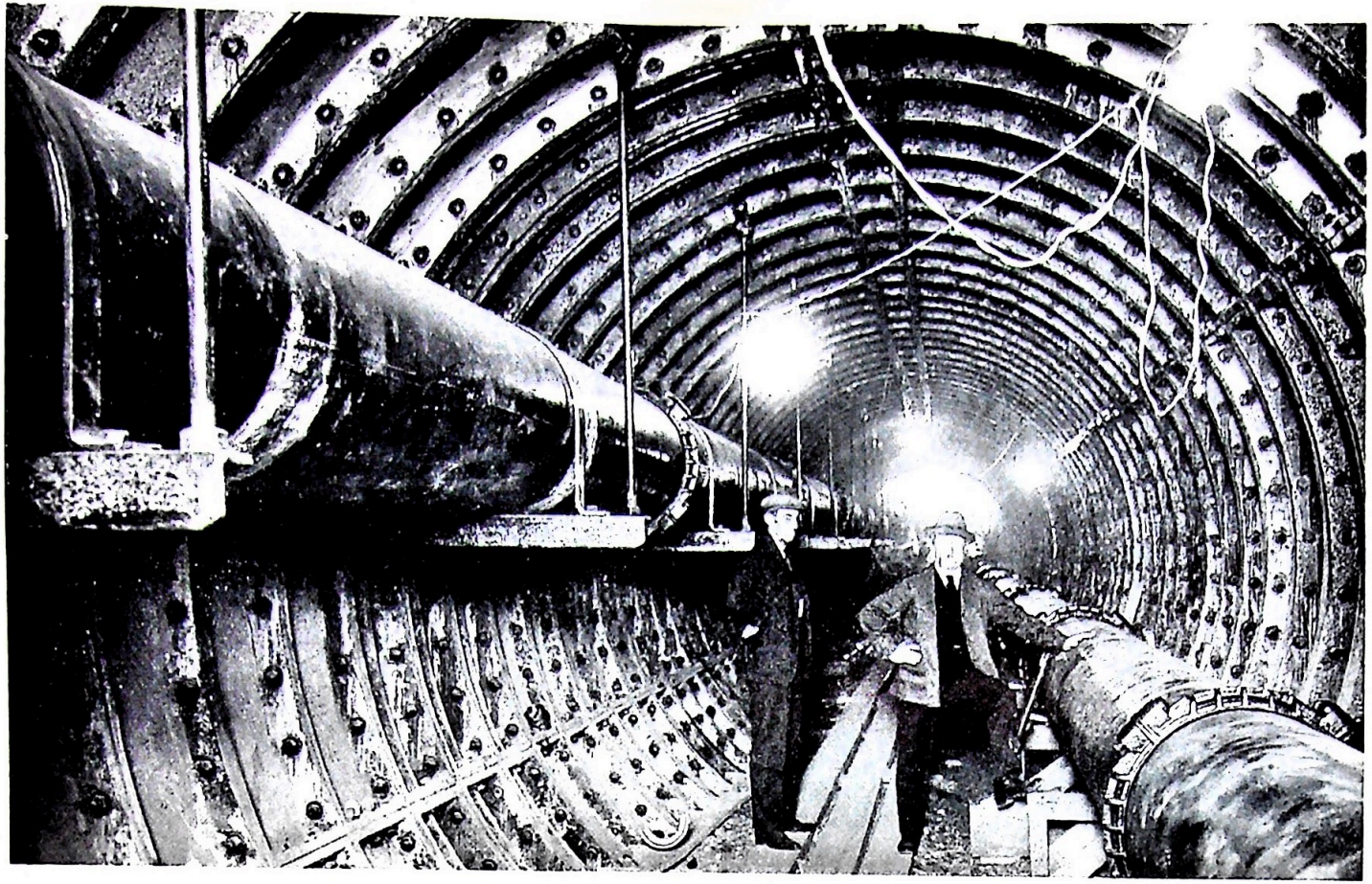
(1) As far as the mains already laid were concerned, nothing further could be done except to inspect and overhaul these when any reasonable opportunities occurred. As to future mains, the relative merits of all available pipe-making materials would have to be considered in relation to the functions of the mains and the soils in which they were to be laid. The issue appeared to concern the use of ordinary sand cast iron pipes, "spun" iron pipes, and steel tubes.

(2) It was not advisable, in view of the varying characters of the sub-surfaces throughout the whole of the Board's area, to prescribe hard and fast rules governing either the use of steel or cast iron pipes. The sub-Committee were of opinion, however, that in future, steel pipes adequately protected should in ordinary circumstances, with due regard to cost, be used for trunk and large high-pressure pumping mains in order to obviate, as far as possible, the occurrence of flooding due to fractures arising from circumstances more generally associated with cast iron. As to the distributing and service mains of the lesser diameters, the sub-Committee found that fractures of cast iron pipes were of infrequent occurrence where they had been laid under modern conditions, and unless special circumstances necessitated the use of steel pipes, the price of these might not warrant their general adoption. The price of steel pipes had, it is true, been reduced, and apart from their strength, they had become a more reasonable financial proposition; but the price was still high when compared with that of cast iron. The effectual protection of the pipes, whether of cast iron or steel, against the attack of both the soil and the water was of the utmost importance, for upon this protection depended their lasting qualities. There was still room for further improvement in this direction.

(3) The protective coating was an even greater necessity in the case of steel pipes because of their relative thinness and liability to perforation by reason of the more rapid wasting of the steel by corrosion. The cast iron pipe did not perforate as easily as steel but was liable to fracture, thus revealing its failure which could then be made good, whereas in the case of steel pipes leakage might go on through the perforations for a long time and remain undetected if the water managed to



SECTION THROUGH A MAIN THOROUGHFARE
showing mains and apparatus beneath the surface



MAINS IN TUNNEL UNDER LONDON

escape into the sub-soil. Hidden leakage of this description was very difficult to detect.

(4) There should be the greatest measure of co-operation between the various statutory undertakers and the local authorities in the Board's area. The adoption of wider measures of co-operation would enable mains to be inspected with a minimum of inconvenience to the general public, and would have the advantage of placing at the Board's disposal earlier knowledge of the conditions of the particular mains exposed as the result of roadworks or otherwise.

(5) Every care should be exercised in the inspection and testing of pipes, whether of cast iron or steel, at the manufacturers' works and in the operations preliminary to and after laying the pipes in the trenches, so that as far as is reasonably practicable any defects may be discovered before the pipe trenches are filled in.

The findings of the sub-Committee were accepted by the Board and have had an important influence on the provision of mains ever since.

The fracture of mains may be due to a variety of causes, including traffic conditions, uneven support, interference with support, fluctuations of pressure, changes of temperature, electrolysis and the corrosion of the metal by the surrounding soil.

During very cold weather fractures may be caused by the admission of water from the exposed filter beds to mains in the ground, which are at a temperature several degrees higher than that of the water entering them. The number of such fractures is fewer in those areas which are supplied with water from wells, which have a more or less uniform temperature of about 50°F.

Many mains after fracture are found to be corroded through soil action and are renewed where necessary. Iron pipes are normally dipped in a hot solution of coal tar pitch, but such protection is insufficient in aggressive clay soils, marshy soils and made-up grounds containing corrosive materials. Additional protection is commonly provided by coating the pipes with bitumen. For the most part the Board's mains are of cast iron, the use of steel pipes being confined to large trunk mains and to special cases such as mains which cross bridges, or are laid

in tunnels or subways. Steel pipes 24 inches in diameter and over are coated and lined with bitumen.

Testing and Stamping of Fittings

The Board in July, 1908, approved the establishment at Battersea of a central storehouse and the centralisation at that station of the whole of the Board's joinery and carpentry work. This was followed in October, 1914, by the adoption of a scheme for centralising the repairing and testing of meters and fittings at Battersea, which work was then being carried out at the works at New River Head and Nunhead. The scheme, however, was still in abeyance in 1922, and the buildings which had been proposed for accommodating the necessary plant had in the meantime been adapted for other purposes.

A meter repair and fittings testing shop had been erected at New River Head by the New River Company in 1899. The work undertaken in the shop very largely increased after the taking over of the companies and ultimately all testing of fittings and the repair of all meters fixed north of the Thames were dealt with there. Whereas in 1899 the New River Company had had to deal with about 60 meters a week, in 1922 meters were passing through the shop at the rate of 135 a week. The number of fittings tested at New River Head had also risen from 122,536 in 1913–14 to 241,132 in 1921–22, in spite of the fact that the Board had at that time no powers to enforce compulsory submission.

It was therefore decided in November, 1922, to extend the existing shop at New River Head. The work was started in June, 1923 and completed in April, 1924.

Following the passing of the Metropolitan Water Board Act, 1932, and confirmation of the byelaws made thereunder, it became obligatory for all fittings to be submitted to the testing station. Arrangements were therefore made to meet the anticipated increase in this work by the adaptation of the existing buildings at New River Head and the provision of additional plant. The number of fittings submitted, however, far exceeded expectations and it became necessary to take a tenancy of a factory in Cynthia Street, Pentonville Road, Finsbury, and to adapt and equip these premises to deal with the excess. A temporary steel framed building was also erected

at New River Head and in order to provide more space the work of repairing meters was transferred to the Battersea works.

During the first year of compulsory testing, 2,127,000 fittings passed through the shop, but after the first heavy influx the number fell off and later settled down to an average of about 1,750,000 a year.

On the outbreak of war, the Board decided to suspend so much of the relevant byelaw as required the compulsory submission of fittings for testing and stamping and the Cynthia Street premises were given up. The testing of fittings submitted voluntarily, however, continued.

After the war the Board were unable to resume full scale testing until proper premises could be built. A scheme was considered for the construction of a combined testing and meter repair shop at Barn Elms works. Designs for this building have been prepared by one of the leading industrial architects, but the work cannot be put in hand until there is some relaxation of the Government's restrictions on capital expenditure.

Communication Pipes

Under section 8 of the Metropolitan Water Board (Charges) Act, 1907, the provision, laying down and maintenance of communication pipes in public highways was the responsibility of the house-owner or the occupier entitled to require a supply of water. Section 19 of the same Act gave an owner or occupier power to open the ground for the purpose of laying and maintaining communication pipes.

In July, 1925, the question of transferring the liability for the maintenance of these pipes was raised by the Ministry of Health, who forwarded to the Board a communication from the Metropolitan Boroughs Standing Joint Committee. This proposed that the liability for the maintenance of such part of each water communication pipe as was under the public highway should be borne by the Board and not by the consumer. The Board decided, however, that the time was not opportune for altering the existing law.

In May, 1927, this question, which was not peculiar to the

Board, was referred by the Minister to the Advisory Committee on Water (a Government Committee).

The report of the Advisory Committee was completed in September, 1929. It advocated the following general policy—(1) That the right to break up the highway should vest solely in the undertakers. (2) That the obligation to provide and maintain supply pipes in or under the highway should fall upon the undertakers. (3) That the expenses in their provision and maintenance should be defrayed by the undertakers themselves, and should not be directly recoverable from the consumer.

In the following year the Property Owners' Protection Association, Ltd., presented the Metropolis Water Supply (Communication Pipes) Bill with the object of transferring the consumers' rights and liabilities regarding communication pipes to the Board, and the Board thereupon decided that the time had come to take action in the matter. They resolved to approve in principle an amendment to the law so as to secure that the provision, laying and maintenance of all communication pipes so far as they were situated under the street should be carried out by the Board, and that the owners' or occupiers' rights to open the streets should vest in the Board.

The Board decided to promote, for this purpose, a Bill in the 1931–32 session of Parliament, which received the Royal Assent in 1932. The Act provided:

(i) That with effect from 1st April, 1933, all communication pipes then existing, with certain minor exceptions, were to be transferred to the Board and the rights and obligations of the Board with reference to the maintenance, repair, renewal and removal of pipes laid down by them were extended and applied to all such communication pipes.

(ii) That with regard to future communication pipes, on and after 1st April, 1933, the Board were granted the exclusive right to provide and lay down the communication pipe with any other necessary and proper apparatus, including a stopcock with a suitable box and cover.

The Board, at the request of a consumer who had laid the supply pipe (i.e., the pipe from the premises to the stopcock in the street) and paid or tendered the water rate in respect of the

premises to be supplied, were to provide and lay down the communication pipe, etc., with all reasonable dispatch, but they might before commencing to do so require the consumer to deposit a reasonable sum subject to adjustment on completion to meet the expenses of so doing.

In the Bill which the Board are promoting in the 1952–53 session of Parliament, provision has been made for abolishing the minor exceptions above referred to, so that all communication pipes will be vested in the Board.

It is difficult to state the total length of piping for which the Board are at present responsible, but there are about 1,373,000 communication pipes and if it is assumed that the average length is 20 feet, the total is rather more than 5,000 miles.

Flooding of the Lee Bridge Works, March, 1947

The worst disturbances to the regularity of the domestic water supply usually arise from frozen pipes or burst tanks or maybe burst water mains. The flooding of the Board's works at Lee Bridge in March, 1947, was an occurrence of quite another order and deserves something more than a passing reference in these pages.

The works at Lee Bridge supply about 34 million gallons per day to a population of rather more than a million persons. There is only a handful of undertakings in this country which supply quantities in excess of this.

The weather conditions in the months of January, February and March, 1947, were exceptionally severe, very low temperatures with heavy snowfalls being prevalent. Thaw set in on 10th March, and was accompanied by heavy rain, resulting in floods which reached maximum heights at New Gauge on the night of 13th/14th March and again on the night of 16th/17th March. The maximum flow recorded before the gauge at Feilde's Weir went out of action was 1,263 million gallons a day, and it is probable that higher flows may have occurred after the apparatus broke down.

Early on Saturday, 15th March, large quantities of flood water began to overflow the flood bank of the Lee Bridge aqueduct which brings the water from the Walthamstow reservoirs to the filters. This water entered the works, which at

about 5.30 a.m. became completely swamped to a depth up to 3 feet. For the first time in their long history, these works were put out of action and a large population was deprived of its normal supply.

All pumps were stopped before the filtered water wells were flooded. As the level of the water in the river Lee at the south end of the works was lower than the flood water in the works themselves, channels were cut in the bank and waste valves opened to drain the water from the works into the river. The only engine house completely flooded contained the electric pumps delivering water to Woodford which were subsequently dismantled and sent away for drying out.

During Sunday, 16th March, the flood water fell rapidly and arrangements were immediately made to enable the Triples electric pumps to discharge to waste. By the afternoon of that day, one pump was working. On the following day it was decided to clean the filter beds which could be isolated from the rest of the works and from which water could be pumped into the Woodford district. The Lee Bridge aqueduct was blocked by a temporary embankment, work on this continuing throughout the night. By the morning of the 18th March, floods were again rising rapidly but none reached the works. The river level began to fall towards the evening of the same day and was down to normal by Thursday, 20th March. The dam was removed on 21st March, and reservoir water was again received at the works in the early hours of the following day. The first filter beds were charged during that day. By 3.30 a.m. on Sunday, 23rd March, all the seven cleaned filters were charged. Samples were collected hourly during the day, the result of the first sample being received at about 4.30 a.m. on the 24th. The result being satisfactory, pumping to Woodford reservoir with the "Musgrave" engine began at 5.30 a.m. The cleaning and setting to work of the remaining beds was put in hand as soon as possible and by Thursday, 3rd April, all except two of the filters were working. The whole of the works were completely out of action for nine days. During that period very great efforts were made to maintain alternative means of supply, to ensure the purity of the water distributed and to repair the damage.

Measures to Safeguard Purity. On the night of 13th/14th March, it was appreciated that there was some risk of flood waters from the Lee entering the Lee Bridge aqueduct, and to ensure that there should be no serious deterioration in the quality of the water reaching the works should this occur, the prechlorination dose was raised from 0.3 to 1.5 parts per million. As an additional precaution the terminal dose was raised sufficiently to provide a residual of 0.7 p.p.m. in the water pumped to supply.

At 10 a.m. on 14th March, routine samples were drawn from mains pumping into supply and samples were drawn hourly thereafter, because ground water might have got into the filtered water conduits. The residual chlorine in these samples estimated in the laboratory after $2\frac{1}{2}$ hours' contact varied from 0.5 to 0.6 p.p.m., indicating a normal amount of consumption. Routine residual tests showed no increase in the chlorine demand and there was thus no immediate indication that pollution had taken place. No chemical deterioration could be detected from the full chemical analyses of the samples drawn on that day. When, however, the bacteriological results were available on the morning of the 15th March, these more sensitive tests showed that 21 of the 28 samples analysed were polluted in varying degree. As it was quite possible that even heavier pollution might have taken place during the night of 14th March, there was no alternative but to advise that all water for drinking and culinary purposes in the affected areas should be boiled.

Random sampling in those districts served by Lee Bridge works in which a pressure supply still existed was commenced on 14th March and by the 19th ninety-two samples had been drawn. Of these only one was shown to contain *Bact. coli.* It therefore seemed reasonable to believe that the high residual chlorine in the water pumped into supply before the works were flooded was sufficient to overcome the pollution in the distribution system and no real anxiety was felt about the possibility of serious consequences. A large area, however, was still without a supply and here the mains were not under pressure. There was therefore a possibility that, quite apart from any contamination that might have reached them during the passage of impure water from the works, they might be contaminated by infiltration of ground water. It seemed

probable that this might constitute the greatest risk to the health of the people.

As soon as the floods had subsided from the works filter bed cleaning was resumed and when the Lee Bridge aqueduct again became available heavily pre-chlorinated water was supplied from it to the cleaned Leyton filters. In the meantime large doses of chlorine had been administered at various points to the filtered water culverts in order to cleanse them as soon as possible and reduce the time required to bring the works back into supply.

Filtration commenced at the filter beds at 10 p.m. on 22nd March, the filtered water being continuously treated with 10 p.p.m. of chlorine and pumped to waste. This rapidly cleansed the culverts and at 6 a.m. on 23rd March the dose of chlorine was reduced to provide a residual consistent with use for domestic purposes. Hourly sampling was commenced and the water was found to be of satisfactory quality, the residual chlorine being well maintained. This stability of the residual chlorine was considered to be of importance as it ensured some measure of protection against any pollution which might have gained access to the empty distribution system.

Although the entire works were not restored to full service until 2nd April, sufficient pure water had become available by 27th March, to permit the restoration of pressures in the distribution system throughout the affected area.

For the whole period random sampling was continued daily in those areas where pressure supplies existed and with few exceptions the results were good. It was not, however, considered desirable to withdraw the advice to boil water until the whole area was cleared and pressures were fully restored, because the possibility existed of contamination from areas in which pressures might still be intermittent and where some pollution might exist.

On 27th March, when pressures had been restored throughout the area, almost all the sample collectors were withdrawn from routine work and a wide sweep was made throughout the district. One hundred and eighty samples were drawn from taps off the mains and from domestic cisterns. Of these one hundred and seventy-nine proved to be negative to *Bact. coli* and

satisfactory residuals of chlorine were recorded almost throughout the area. The results were considered to be sufficiently good to justify the removal of the boiling notices.

Additional supplies. Additional Thames water was passed into the affected area *via* the Thames subways and bulk supplies were received from the South Essex, Sutton and Herts & Essex Water Companies. Croydon Corporation also assisted by reducing their "take" under their bulk supply agreement with the Board by about 1 million gallons a day. In this instance the Corporation obtained an Order from the Ministry of Health to increase their "take" from the Waddon well.

Distribution of water by tank waggons. Immediately the supply was interrupted, emergency supplies by tank waggons were put into operation. This was a large task. The Board had a considerable number of their own tank waggons but these were quite inadequate to meet the situation. A large number of tanks, tanker waggons and other transport was obtained from outside sources, including water undertakings in the Greater London area, the War Office, Air Ministry, local authorities in and around London and from towns as far away as Sheffield, Leeds, Bradford and Barnsley. Some of the drivers from the provinces travelled throughout the night in spite of rain, sleet, snow and flooded areas, but all arrived in a surprisingly short space of time. By means of this combined operation a supply to a population estimated at between 300,000 and 350,000 persons was afforded.

As is so often the case at a time of crisis, everybody worked in unison. Voluntary organisations helped by providing guides for the lorries and organising residents in the various local districts when lorries arrived. Meals for the men were provided by mobile canteens and payment of their wages was made on the spot so as to ensure the minimum interruption of the work. The public cut off from their normal supplies patiently endured the hardships involved which included not only shortage but also queueing at the distribution lorries. The B.B.C. and the Press co-operated with the Board in giving publicity to appeals and directions. The staff, too, played their part.

At the peak of the emergency no less than 1,010 tanks and tankers were in service. These included 400 supplied by H.M. Forces. About 14 million gallons of water, sufficient to supply a large town, were delivered by this means.

At their meeting on 21st March, 1947, the Board gave expression to their keen appreciation of the assistance rendered by all concerned.

CHAPTER XVIII

Engineering Organisation

As has already been observed the engineering department had by 1913 been divided into four districts while certain major supply works had been brought under direct central control.

Experience of that arrangement revealed some defects which, in the interests of efficiency, economy and uniformity of treatment, it was desirable to overcome. Thus, each district engineer maintained his own drawing office staff and in addition a staff dealing with charges for accommodation works carried out by the Board for a large number of public bodies. Officers in the district communicated with their office only in writing or by telephone, and they could as easily report to a central office if they were controlled from there.

When therefore the question of accommodation in the new central office at New River Head was considered it was decided to take the opportunity to effect further centralisation, but war prevented the completion of the new office until 1920.

After the death of Mr. Bryan in 1914 and the appointment of Mr. Restler to succeed him, the position of deputy chief engineer lapsed. In 1916, a functional organisation was evolved which provided for a supply, a distribution, and a new works engineer, each to have charge of one branch of the work throughout the area and to be directly responsible to the Chief Engineer. In the absence of the Chief Engineer each was to be authorised to report directly to the Works and Stores Committee. For a variety of reasons the scheme was not fully implemented. In 1923, the appointment of a deputy chief engineer was revived, and in the following year the positions of chief civil engineering assistant and chief mechanical engineering assistant were created. This in no way impaired the control exercised by the district engineers.

In 1937 it was decided to divide the functions of distribution and supply on the north side of the Thames. This involved the

amalgamation of the Northern and Western districts and a supply and a distribution engineer were appointed for the combined areas. The supply engineer was made responsible for the collection and preparation of water in bulk, and for river intakes, wells, storage reservoirs, filtration and chemical treatment. The distribution engineer was made responsible for conveying the purified water to the consumer, and had charge of trunk mains, service reservoirs and distribution and service mains. The waste, meter and fittings sections subsequently came under his control.

The supply works on the northern side of the Thames and in the Hampton group and the staffs necessary for their supervision fell into two groups—the Thames and the Lee valley. The Thames valley group included the Staines, Laleham, Walton and Hampton intakes; the Queen Mary, Staines, Walton, Hampton, Barnes and Barn Elms storage reservoirs; and the Hampton, Kempton Park, Walton, Surbiton, Kew, Barnes, and Barn Elms filtration works. The Lee valley group included the New Gauge, Enfield and Chingford intakes; the New River; the King George's and Walthamstow reservoirs; the New River Head, Stoke Newington, Hornsey, Lee Bridge, Ferry Lane and Rye Common filtration works; and all the wells north of the Thames. A resident supply engineer was appointed to take charge of each group.

The distribution engineer's area was sub-divided into three smaller areas called the Western, Central and Eastern areas, corresponding to the Western district and the two divisions of the Northern district. Each of these smaller areas was placed in charge of an assistant distribution engineer.

The mechanical engineer, formerly the chief mechanical engineering assistant, was made responsible for the pumping machinery of the two former districts and of the Hampton group of works. These were divided into three groups each of which was placed in the immediate charge of a resident mechanical engineer, as follows:

Hampton Group—The Staines, Littleton, Hanworth Road, Kempton Park, Hampton, Walton and Surbiton stations.

Western Group—The Kew Bridge, Hammersmith, Barnes, Barn Elms, Campden Hill, Barrow Hill, Willesden and Cricklewood stations.

Lee Valley Group—The New River Head, Lee Bridge, King George's reservoir, Greaves, Stoke Newington, Hornsey, Fortis Green, Woodford, Hornsey Lane and Cheshunt stations and all the well pumping stations north of the Thames.

The designation of the chief civil engineering assistant was changed to that of new works engineer. A planning engineer was appointed in 1943.

The Kent and Southern districts were brought into the scheme on the retirement of the district engineers in 1939 and 1947, respectively.

CHAPTER XIX

The New River

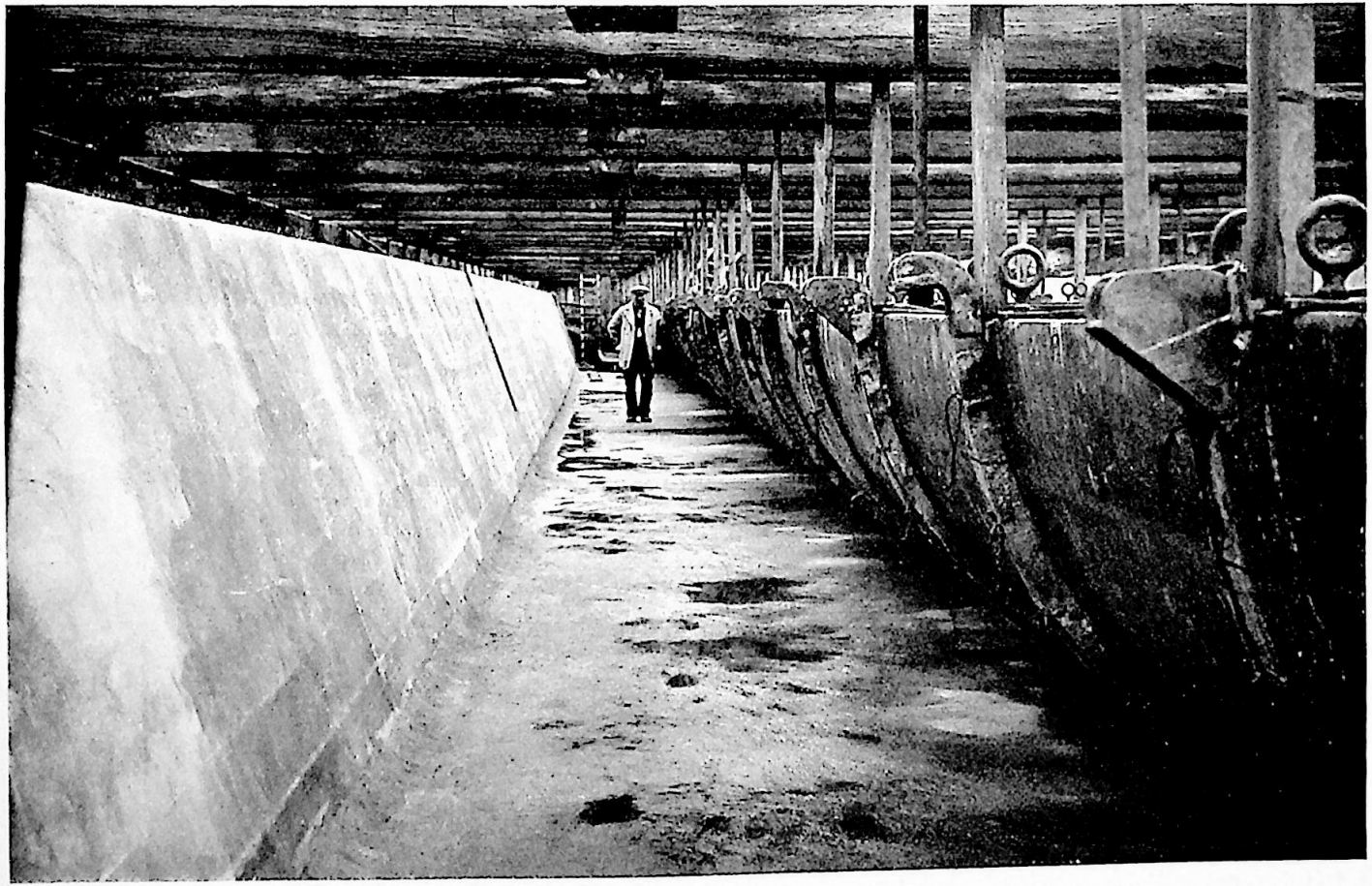
No part of the Board's undertaking is richer in historical associations than the New River which this year completes 340 years of its existence. It still remains as a remarkable engineering feat and adds beauty to the scene wherever it appears.

The course of the River has remained practically unaltered since 1903—in marked contrast to the preceding 50 years when its length was ingeniously curtailed by cutting off some of its loops caused originally by following the ground contours.

One night in October, 1940, a bomb smashed the pipes carrying the water to the filtration works lower down its valley and it was necessary to re-open the old Enfield Loop and revert to the channel's original course. As a result of this incident negotiations took place with the Enfield Urban District Council, to whom the Board had conveyed the "Loop" in 1938, and it was returned to the Board in 1942. In November, 1952, after further prolonged negotiations the Board agreed to convey the Loop to the Council for a second time.

The flow from Chadwell Spring—the original source of the New River—is virtually a thing of the past and the yield, if any, is insignificant. Few people will now remember the interest shown in this yield by Parliamentary Committees and Royal Commissions during the last century and the efforts of the New River Company to enlighten them on the subject.

The New River still plays a very useful part in London's water supply system and Sir Hugh Myddelton, were he to see it now would not be disappointed at its present role, for it still brings some pure water down its course, albeit well water instead of spring water. Nor would he object to the River Lee water which the "river" takes in at New Gauge, near Hertford, for he himself was the first to have recourse to that source for assistance.



TROUGH CARRYING THE NEW RIVER DURING CONCRETING OF BED

PRIMARY FILTER HOUSE, STOKE NEWINGTON

The New River enables the Board to draw 22½ million gallons a day from the upper reaches of the River Lee at New Gauge and to supplement this supply from wells sunk by the old Company along its valley. The water feeds the filtration works at Hornsey and at Green Lanes, Stoke Newington, lower down the valley.

The works at Hornsey remain much as they used to be, apart from the replacement, in 1937, of two pairs of old compound beam engines by oil engines driving centrifugal pumps. A one and a quarter million gallon contact tank is being constructed here.

At Stoke Newington, on the other hand, considerable additions have been made. Twelve primary filters were built in 1936, to deal effectively with algal growths which were continually interfering with the working of the filter beds and reducing the yield from the station. The plant is capable of dealing with 32 million gallons a day. At the same time six electric low lift pumps were installed to raise the water from the primary filters to the slow sand filters. In 1946, an electric pump was set to work at the station to help the old compound beam engines inhabiting William Chadwell Mylne's "Scotch castle". (His ancestors were Master Masons to the Crown of Scotland.) This extraordinary engine house was built in 1855, and among its peculiarities is the arrangement of the old engines whose flywheels were made to fit into its buttresses bearing Mylne's monogram. A scheme for the replacement of all the old machinery by electric pumps has been in progress since 1945, but four of the old beams are still being retained for standby purposes. Here again, a contact tank of three and one-third million gallons capacity is being constructed.

Along the course of the River some of the engine houses feeding it with well water appear large in relation to the plant which they now contain, the old steam-driven machinery which they were built to house having been replaced by small electric pumps. This has been the case at Rye Common which was converted to electric drive in 1935, the first of the Board's well stations to undergo this change. Other New River stations similarly treated were Amwell Hill in 1944 and Hoddesdon and Broxbourne in 1946. Hoe Lane and Turnford stations are in course of remodelling. At the latter station an old marine

type Boulton and Watt engine which in the 1840's used to pump water from a well in what is now Tolmers Square, at the back of Hampstead Road, is being preserved in its present position. The engine is fitted so tightly in the building that one wonders how it was ever assembled inside.

Much care has been devoted by the Board to the maintenance of the River. The renewal of the puddle clay of the bed and the re-wharfing of the banks has been undertaken with greater thoroughness perhaps than at any time during the previous three hundred years. In certain places the whole channel has been concreted. This was done near Amwell Marsh and opposite Amwell pumping station in 1907, to prevent leakage from the river. The river was treated in the same way between Amwell Pond and Amwell Hill in 1930, with financial assistance from the Unemployment Grants Committee, and again in 1934. While the concreting was in progress the water had usually to be carried in a large trough suspended from timbers spanning the channel.

In 1914, the first step towards abandoning the Clerkenwell portion of the New River was taken when the Round Pond, the New River Head itself, had to be taken out of commission to make way for the Board's new Central Office. The river continued to feed the three filter beds at this place, however, until 1936, when the first filter bed was taken out of service to make room for the new Laboratories. Then in March, 1946, the remaining filter beds were abandoned after it had been decided to end the river at Stoke Newington works. In 1950, the pipes laid in the latter half of the last century for carrying the river underground most of the way from Stoke Newington to New River Head were excavated. It is of interest to note that some of these pipes were subsequently used to connect the King George's reservoir and the William Girling reservoir, in the Lee valley.

At New River Head the two triple expansion engines which formerly raised the filtered water to Claremont Square and Crouch Hill reservoirs were taken out of the old engine house (dating from 1818), after small electric pumps had been installed in 1950. The water pumped at New River Head now comes from Walton *via* Battersea.

The original cost of the New River

This short account of the New River would not be complete without mention of some interesting historical research undertaken a year or two ago designed to unveil the mysteries associated with its financial history.

In the past much has been said and written about the cost of the New River, some of it bearing the stamp of authority and some being obviously conjectural. As a result of the research undertaken, however, new light is thrown on the whole project.

Throughout the last century Commissions and Committees of Parliament accepted as fact that since the destruction of the New River Company's early records by a disastrous fire in 1769 no records existed showing the original cost of the New River.

The estimates which were made were, for the most part, extremely high.

Samuel Smiles in his "Lives of the Engineers" dated 1861, was evidently not satisfied with wild guesses and endeavoured to find out what had actually been spent on the project. He apparently consulted the printed Calendar of State Papers and other publications, arriving at a figure of £17,000. An examination of the original documents disclosed, however, that his calculations were partly based on a misprint.

The facts are of some historical interest. On 1st November, 1611, that is some two years after the work of constructing the New River had commenced, an agreement was entered into between King James I and Hugh Myddelton, whereby the King undertook to provide half the cost of the construction and maintenance of the New River in return for half the profits derived therefrom. Myddelton was to render an account of his expenses to the Lord High Treasurer. The accounts so rendered are preserved at the Public Record Office and provide an authentic statement of the cost of the New River and a very interesting record of the manner in which it was constructed. The whole of the cost as ascertained amounts to £18,525 0s. 1d. This figure covers the period from 20th February, 1609, to 26th November, 1614, that is fourteen months after the water had been brought to New River Head (29th September, 1613), and by which time some mains had been carried into the City and several houses supplied.

Many other interesting facts emerged from this research. The accounts are written in simple English but the handwriting is of course seventeenth century and some of the words used are now obsolete. The work and its problems are brought to life in a unique way and at the same time some of the myths surrounding this historic undertaking are dispelled.

CHAPTER XX

From Source to Consumer

THE foregoing chapters have described in some detail the historical development and present functions of the major engineering works. The present chapter attempts to draw these threads together and to provide the reader who is unfamiliar with the internal operations of the Board, with a simple description of the water supply arrangements as a whole. In so doing there will be occasional repetition of what has been recorded elsewhere but trespass will be kept to a minimum.

The Board's supplies are obtained from the River Thames, the River Lee and from wells and springs mainly in the Lee valley and Kent areas. Of these the River Thames provides about two-thirds of the total and each of the other sources about one-sixth.

During the year 1951/52, the average daily supply was 322 million gallons, of which the Thames contributed 220 m.g., the Lee 54 m.g. and wells 48 million gallons. The total is greater than the combined supplies afforded to the cities of Manchester, Liverpool, Birmingham, Sheffield, Leeds and Bradford. The supply from the wells alone is equal to that of a large city.

These average quantities are greatly exceeded at times of maximum demand. The Board have been called upon to supply over 400 million gallons per 24 hours on several occasions (the highest supply so far recorded was 428 m.g. on 2nd June, 1947), and it is possible that the peaks will eventually reach new levels.

The fact that most people in the Board's area are dependent either wholly or partly upon the River Thames for their water supply provides a reason for describing the system in relation to that source. Substantially the same process operates in the case of the River Lee. In the case of areas deriving supplies entirely from wells, the arrangements are more local and simple.

From the time water is abstracted at the source until it reaches the consumer's premises it passes through the following stages:—

(i) abstraction and storage, (ii) filtration, (iii) pumping, and (iv) distribution.

These processes are illustrated in the diagram at the end of the volume.

River water is abstracted through intakes provided with screens for arresting branches and floating debris.

On the River Thames or its tributaries there are fifteen intakes, but only two, Laleham, 15 miles above Teddington Weir, and Walton, 7 miles above Teddington Weir, are in regular use.

Of the others, one at Staines is used intermittently, whilst the remainder are only opened in an emergency.

Water from the River Lee is abstracted at the New River (New Gauge) intake between Ware and Hertford, at Enfield, and at Chingford Mill.

The design of the intakes varies considerably, the largest being that at Laleham. Here the water is controlled by Stoney sluices and is measured by three 100 million gallons per day Venturi meters. Some of the older intakes at Hampton on the other hand, consist merely of a large pipe built into the river wall. At the New River intake there is a floating regulating gauge which normally permits a maximum of 22.5 million gallons per day to pass into the New River.

Storage

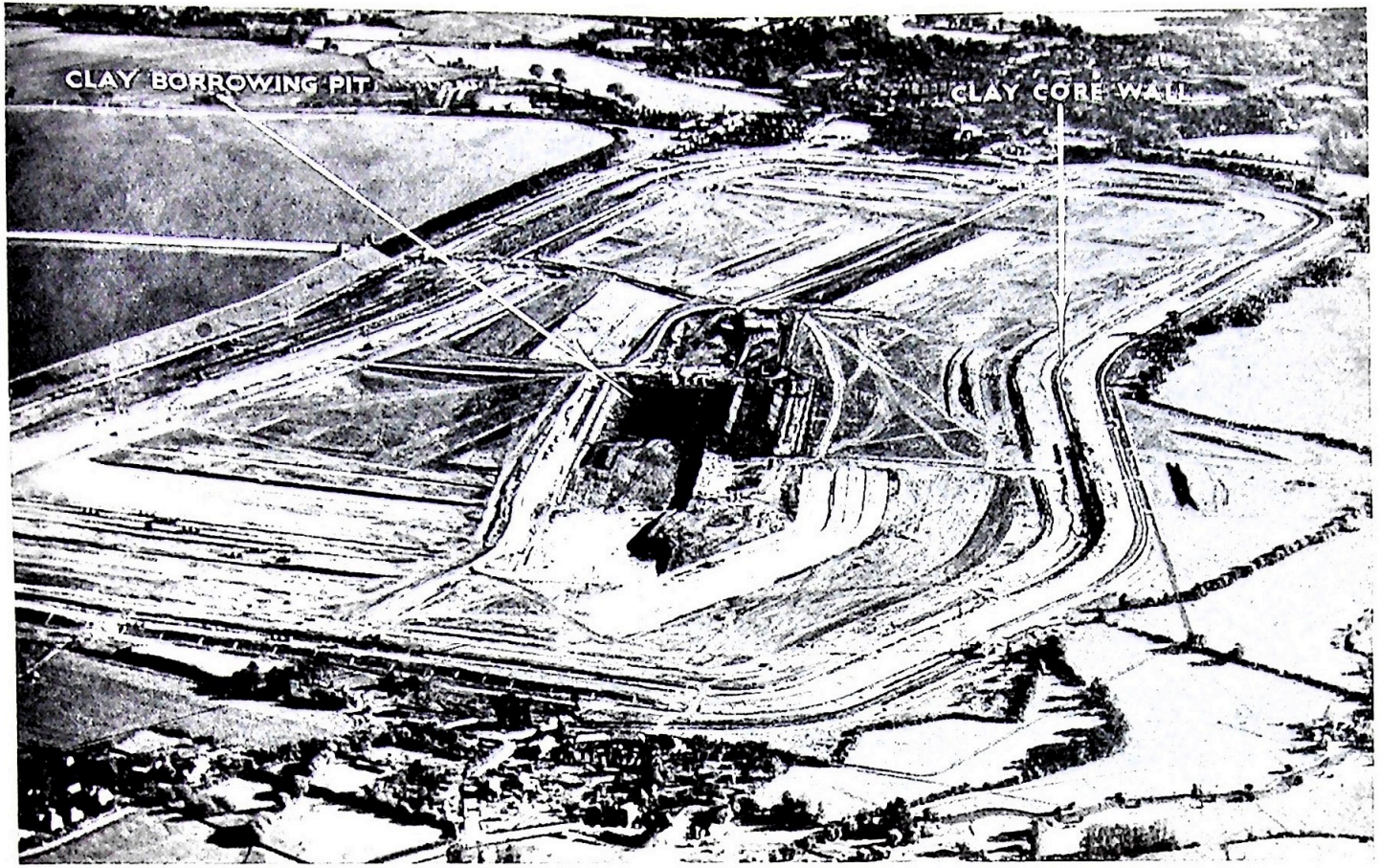
From the intakes water is pumped into storage reservoirs where its quality is very considerably improved; suspended matter falls to the bottom and nearly all of the disease-producing or pathogenic bacteria, which may be present in the river water, die out. The quality of the water is stabilised and in stored waters is not liable to the sudden fluctuations which characterise river waters.

Unfortunately, storage has one serious disadvantage. It provides a suitable opportunity for the development of heavy crops of algae—minute plants which seriously impede filtration and many of which impart to the water a variety of tastes ranging from "grassy" and "weedy" through "geranium"

By courtesy of Sir William Halcrow & Partners

75-INCH THAMES TO LEE VALLEY MAIN

Inside the experimental length showing the entrance to the tunnel



A STORAGE RESERVOIR UNDER CONSTRUCTION

to "fishy" and "pig-pen." These algae thus play a significant part in all stages of purification and it is not too much to say that without their occurrence purification would be a relatively simple matter.

The largest of the storage reservoirs are the "Queen Mary" at Littleton, the "King George the Sixth" at Staines, and the "King George's" and the "William Girling" reservoirs at Chingford.

The method of construction of the Board's storage reservoirs is based on the existence of a thick stratum of impervious London clay underlying the ballast which covers large portions of the Thames and Lee valleys.

A reservoir is formed by the construction of a continuous embankment enclosing the whole area. The first operation is to sink a trench on the centre line of the embankment down through the ballast into the London clay. This trench is refilled with clay puddle up to the original surface level, thus providing a continuous watertight cut-off wall below the ground.

Above ground, this clay puddle curtain is continued vertically up through the heart of the bank, which is composed of ballast excavated from the interior of the reservoir. This excavated material is spread in thin layers and thoroughly consolidated by rolling. A thickness of selected material of a more clayey and retentive nature is then placed on each side of the puddle core wall between it and the ballast of which the main body of the bank is composed.

The inner or water face of the bank, which has a slope of, say, 1 in 3, is protected from erosion by concrete slabs, 6 and 4½ inches thick, at the top of which a head wall with a coping so shaped as to reflect waves without causing spray, is formed in reinforced concrete.

On its outer face, the bank has a slope of about 1 in 2½ and is covered with a layer of soil sown to grass.

The London clay from which the clay puddle is prepared is obtained from a large "borrow pit" in the interior of the reservoir which is subsequently refilled with ballast.

The sinking and refilling of the cut-off trench, the formation of the embankment, the winning of clay for puddle and ballast for concrete, involve the excavation and removal of very large quantities of material. In the case of the King George the Sixth

reservoir at Staines it amounted to $6\frac{1}{4}$ million cubic yards.

It is difficult to visualize this quantity but the following illustration may serve to indicate its magnitude:—

The open space at Trafalgar Square, inside the line of the surrounding buildings and including the roadways, has an area of 5.32 acres. If $6\frac{1}{4}$ million cubic yards of material was piled in a solid mass with vertical sides on this area it would bury it to a depth of 730 feet or twice the height of St. Paul's Cathedral.

Filtration

After circulation in the reservoirs, water is passed to the filtration plant. At one time slow sand filters were used by themselves, but there are disadvantages in so doing, namely, slowness of operation and the large acreage of beds necessary to give the required output. The Board, therefore, employ a system of double filtration consisting of roughing or rapid filter beds in the first place and secondary or slow sand beds afterwards. The roughing filters are of the open gravity type, operating without a coagulant (see page 251), and are cleaned by blowing a strong current of air up from the bottom, followed by a wash of clean water. By their means, partially filtered water is supplied to the slow sand beds, the output of which is, in consequence, considerably increased, troubles from algal growths are reduced and operational costs lessened. The primary filtration plant is designed to have an average rate of twenty feet per hour.

Primary filtration plants are now in operation at Hampton, Kempton Park, Walton and Barn Elms in the Thames valley and at Stoke Newington in the Lee valley.

Slow sand filters consist of rectangular basins, in the floor of which collecting channels are formed, the whole floor being covered with a continuous system of underdrains comprising bricks spaced apart, perforated tiles or porous concrete. On top of the underdrains is spread a layer of gravel about 4 ins. to 12 ins. thick in graded sizes, the coarser at the bottom and the finer at the top. Above the gravel, forming the top of the bed, is a layer of sand 2 ft. to 2 ft 6 ins. in thickness. Water is passed on to the surface of the sand to a depth usually of about 4 ft. 6 ins. It percolates downwards, at a rate of 4 ins. to 8 ins. per hour, through the sand and gravel and in so doing leaves

behind, on the surface, any suspended matter which it may have contained. A film of silt, debris and micro-organisms is thus formed and this film is capable of holding back even bacteria. As the film develops it gradually reduces the rate of filtration until it is necessary to shut off the bed for cleaning. For this purpose about three-quarters of an inch of the sand is removed and washed, the impurities being carried away to waste in the wash water, and the clean sand is used again to replenish the beds.

The Board have 13 filtration stations, the most important of which are at Hampton, Kempton Park, Walton, Surbiton, Barnes and Barn Elms, Lee Bridge and Stoke Newington. A large new station is nearing completion at Ashford Common.

When the water leaves the secondary or slow sand filters it receives a small dose of chlorine, which acts as an additional safeguard. Sterilisation is not an instantaneous process, but is governed by the dose of chlorine applied and the time during which it is allowed to act. This dose is varied according to the conditions prevailing and to the quality of the water. Large tanks, known as contact tanks, are provided to hold the filtered and chlorinated water for a sufficient period to ensure complete sterilisation and to enable the water to be passed into supply free from objectionable tastes.

Pumping

Since all the Board's water is either river-derived or obtained from below ground, maintenance of the supply is entirely dependent upon continuous pumping.

The machinery presents a great variety of types and sizes, ranging from such small repumping sets as the 1 water-horse-power electric units at Shoreham to the 3,000 horse-power steam-turbine-driven pumps and generators at Hampton, and from the 2-foot lift required of a filter pump at Surbiton to the 550-foot head imparted by the diesel-driven multi-stage pumps at Sundridge.

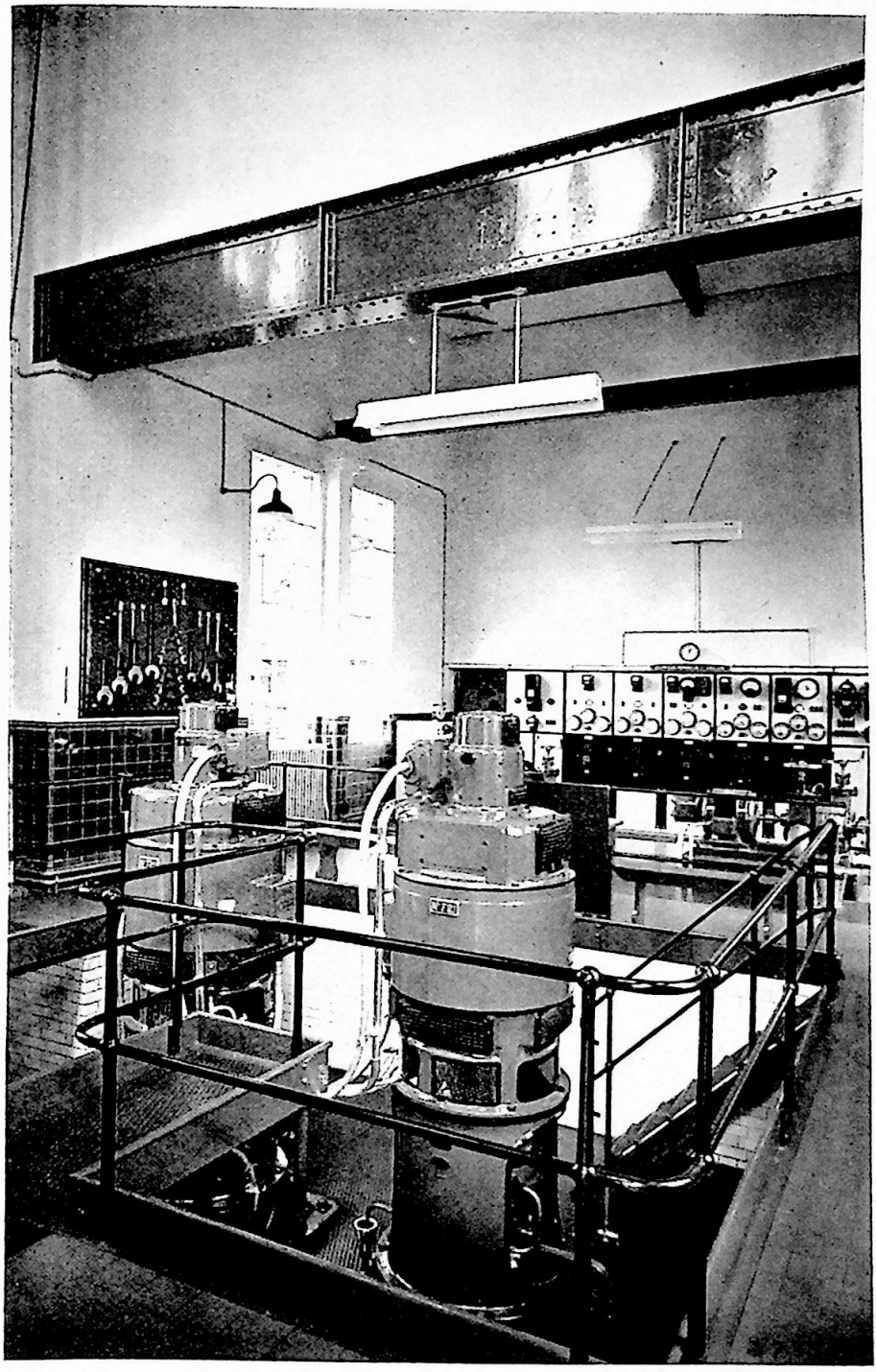
The total horse-power of the Board's pumps exceeds 66,000, of which about 70 per cent is derived from steam-driven plant, 12 per cent from oil engines and 18 per cent from electric pumps.

The duties required of the pumping plant consist in the main of: (i) raising raw river water into storage reservoirs and pumping out of these when necessary, (ii) pumping filtered water into supply and repumping where required for higher zones, and (iii) raising water from below ground to the surface and forcing it into supply.

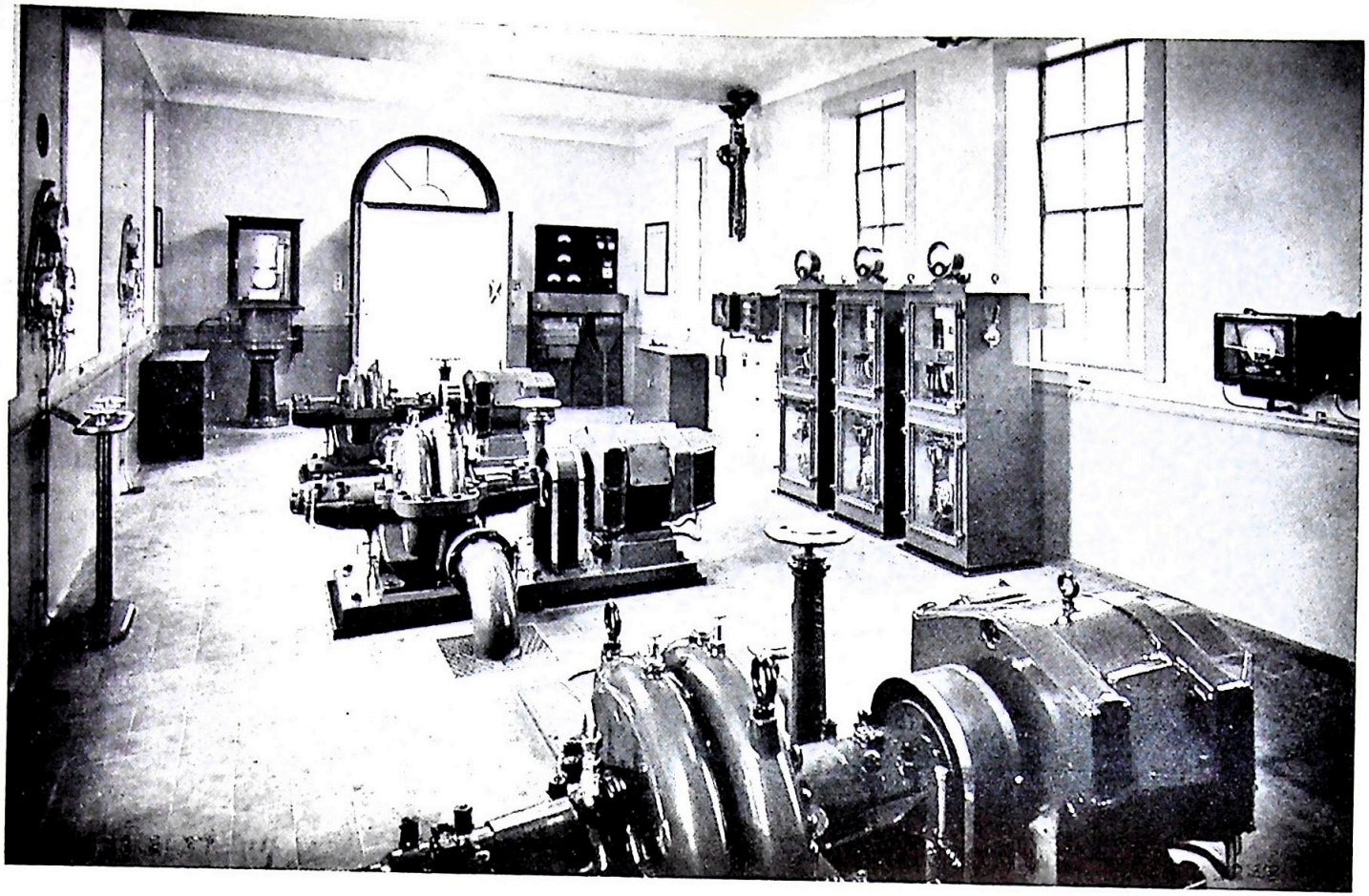
Raw water pumping machinery has, in general, to deal with large quantities against small heads. The machinery is of various types. For supplying the "Queen Mary" reservoir there are centrifugal pumps of a total capacity of 300 million gallons daily. At Staines steam-driven reciprocating pumps are installed. At Walton triple-expansion steam engines drive centrifugal pumps. The "King George's" reservoir in the Lee valley is supplied by five Humphrey pumps, four having a capacity of 40 million gallons a day each, and the fifth, one-half this amount. These remarkable pumps, which depend for their action on the inertia of large columns of water, are driven by producer gas. The power for the raw water pumps at Hampton is derived from steam turbines.

The greater part of the water-horse-power produced by the Board's pumping plant is required for forcing filtered water into supply. Further, the nature of the Board's area is such that some of the water pumped to a head sufficient for a part of the population has to be repumped for consumers on higher ground or in the more remote districts. In a number of cases water is pumped as many as three times after filtration. As a result, the type and sizes of the filtered water pumping machinery vary greatly and, due to the fluctuations in the demand at different times of the day, great flexibility is required in the individual pumping units.

Steam turbines driving centrifugal pumps and reciprocating steam engines and pumps compose some of the Board's largest pumping installations for delivering filtered water into supply, but in recent years the competition of the oil-engine and, more particularly, of the public electricity supply, have become more marked. Diesel engines offer considerable advantages in respect of high thermal efficiency under varying conditions and low upkeep costs, although their fuel and lubricating oils have to be imported. Electric pumps, on the other hand, consume home-produced fuel and require even less attendance than diesel



ELECTRIC PUMPS, RYE COMMON



BOOSTER STATION, PUTNEY HEATH

engines. They are, however, dependent upon a source of energy whose failure could cause serious interruption to the Board's supply, and every important station driven by purchased electric power is therefore provided with standby plant, generally in the form of diesel alternators.

A disadvantage of alternating current electric drive is that the moderate speed variation desirable to provide flexibility is not easily attainable.

The Board have in normal operation 40 well stations. At most of these, pumping takes place in two stages so as to allow of chlorination and contact in a low-pressure tank at the surface. In the case of most of the New River well stations the water is delivered at surface level only, into the river.

Before the advent of electric drive all well and borehole pumps were of the reciprocating type, and a number of these, mainly steam-driven, are still in operation. Of late years, however, the vertical-spindle centrifugal pump, itself located near the water level but driven through shafting by an electric motor at the surface, has come into prominence. More recently still, the driving motor has been made submersible and both motor and pump placed below the water level, thereby avoiding the use of shafting and greatly increasing the ease of manipulation. The Board first installed a pump of this type, for permanent use, at Jewels Wood in 1943. Both types have, as contrasted with the intermittent action of the reciprocating pump, the advantage that water can be extracted at a steady rate from a borehole. As the majority of well and borehole stations are restricted in size, the saving in labour possible with electric drive is proportionally great, and it is likely that future installations will be of these types.

At some stations diesel engines drive through gearing centrifugal pumps and electric generators, the power from the latter being used for working electric pumps situated below ground. At a number of others, motors running on purchased electric power are driving borehole pumps.

The boiler plant consists of some 141 boilers, many of which are mechanically fired, while at the newer stations the latest devices for handling coal and ash are installed.

The constant pumping required throughout the Board's system involves the consumption of very large quantities of

fuel amounting at the present time to some 120,000 tons of coal, 1,150,000 gallons of oil and 50,000,000 units of electricity in a year.

Distribution

The water is pumped to consumers through an intricate network of underground mains and does not again see the light of day until it reaches their premises. The distribution system includes over 8,500 miles of mains ranging in size from 2 ins. to 48 ins. in diameter. There are upwards of 570 miles of mains of 24 inches diameter and over, but the greatest proportion of the distribution network is composed of 4-inch pipes of which there are more than 4,320 miles or over 50 per cent. of the total length.

The eight separate distribution systems inherited by the Board were only connected at a few points. During the period covered by this Review these have been gradually merged and by means of an elaborate system of intercommunication alternative methods of supply are now available for most areas.

Since neither the London water nor the soil—except in the case of certain clay areas—has any markedly deleterious effect on cast iron or lead, there are to-day cast iron mains of over 100 years of age in service and in excellent condition. "Spun" that is centrifugally cast, iron pipes are also used with satisfactory results, and where cast iron mains are laid in clay areas the pipes are protected by a sheathing of bituminous composition.

In order to meet particular and unusual service conditions which arise from time to time, steel pipes lined internally and sheathed externally with bituminous composition are sometimes used for service. It is now the practice to use such pipes for all trunk mains of 24 inches diameter or over.

The principal trunk mains are those carrying water in an easterly and north-easterly direction from the Thames valley and western stations, and they include no fewer than 27 mains of diameters between 21 inches and 48 inches. Another important group of trunk mains conveys water southwards from the works on the New River and the Lee.

Some of the trunk mains are of considerable length. For example, the 48-inch main from Kempton Park to Bishop's

Wood reservoir, Highgate, is 17 miles long; the length of the 36-inch main from the same station to Finsbury Park is 19 miles, and that of the 42-inch main from Hampton to Nunhead is 16 miles. The maximum pressures in the trunk mains generally do not exceed 300 feet, those in the three mains referred to being 295, 180 and 230 feet respectively.

Integral with the distribution system are 85 service reservoirs situated on high ground and containing a total of 255 million gallons, but since the majority of the consumers' premises are situated between the pumps and the reservoirs the latter act mainly as "jack-heads." During the day, when the demand is greatest, water flows out of the service reservoirs to augment the supply from the pumping stations. They fill up again at night when the demand falls off.

The highest service reservoir is that at Betsom's Hill in Kent, the top water level being 818 feet above O.D. The largest is at Honor Oak in South London, and contains 56 million gallons.

Concurrent with these engineering operations is the work of water examination and purification, described more fully in the chapters immediately following.

CHAPTER XXI

Water Examination—General Remarks

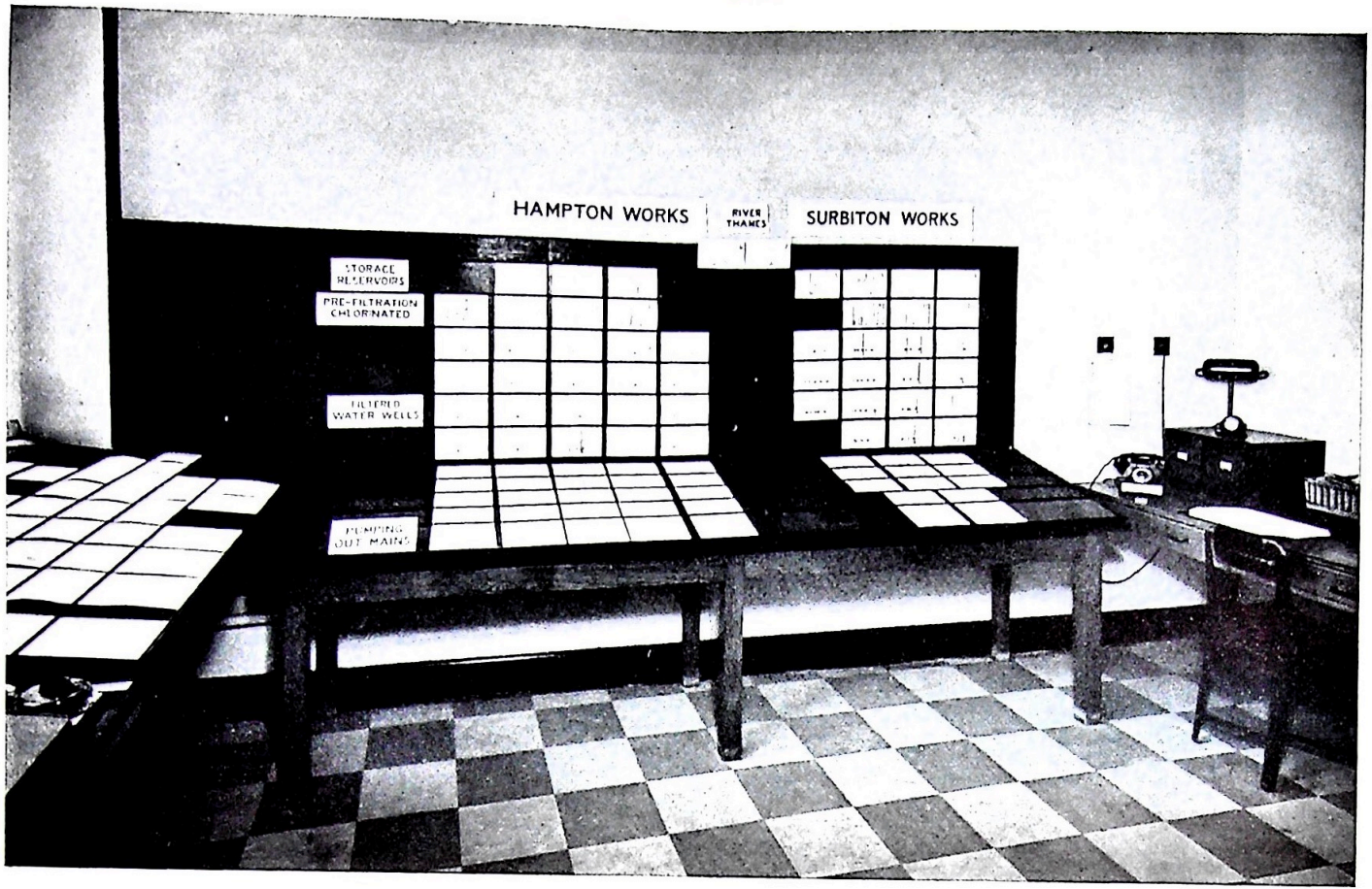
THE work of ensuring the purity of the water delivered to consumers is one of the Board's vital tasks. It is also one with which the average consumer is little acquainted, chiefly because it goes on behind the scenes. The present chapter and the three succeeding ones are devoted to an explanation of this branch of the work.

Section 25 of the Metropolis Water Act, 1902, placed upon the Board the express duty of providing for the chemical and bacteriological examinations of water to be supplied to the consumers. The section reads as follows:

> "(1) The Water Board shall cause to be made chemical and bacteriological examinations of and experiments as to the condition of the water to be supplied by them.
>
> "(2) The Water Board shall supply such buildings, apparatus and plant, and such staff, and construct such works as may be required for enabling such examinations and experiments to be conducted efficiently.
>
> "(3) The persons employed by the Water Board to make examinations and experiments under this section shall periodically report to the Water Board the result of their examinations and experiments and a copy of the report shall at the same time be sent to the Water Examiner.
>
> "(4) The Water Board shall take and record such observations as may be required by the Local Government Board.
>
> "(5) The Water Examiner shall, at all reasonable times, have free access to the works of the Water Board for the purpose of inspecting those works, and shall have all proper facilities for making such inspection."

The office of Water Examiner of the Metropolitan water supply was created by the Metropolis Water Act, 1871. Under this Act the Water Examiner was to be appointed by, and report to, the Board of Trade. The Public Health Act of 1872, however, transferred these Board of Trade functions to the Local Government Board. The Water Examiner inspected the various companies' works, conducted regular examinations of raw and

THE LABORATORIES OF THE WATER EXAMINATION DEPARTMENT



SECTION OF THE CHART ROOM, WATER EXAMINATION DEPARTMENT

filtered water and issued monthly and annual reports on the Metropolitan water supply.

The office was abolished by the Board's Various Powers Act of 1921, following the report of the Monro Committee, which commented favourably on the work of the Board's Water Examination department.

At the "appointed day" the water supplied by all the companies, with the exception of the Kent, was subjected to examination by Sir William Crookes and Sir James Dewar. The water of the Kent company was analysed by Professor Percy F. Frankland. Examinations previously undertaken by the London County Council's chemist were continued at the Board's request on a three-monthly basis.

The Board were anxious to place the examinations on a uniform basis and accordingly, in March, 1905, decided to discontinue the examinations conducted by Professor Frankland as from June, 1905, and to extend the examinations undertaken by Sir William Crookes and Sir James Dewar to the Kent district. These two gentlemen had in the meantime been engaged with Dr. A. C. Houston to report in conjunction with the Chief Engineer on the steps necessary for discharging the Board's statutory duties. This report was presented to the Board in May, 1905, and contained recommendations relating to the collection and testing of samples of raw and filtered waters and the establishment of a central laboratory, properly equipped, on property belonging to the Board at Campden Hill. Reference was made to the opinions expressed in the report of the Llandaff Royal Commission that frequent bacteriological as well as chemical examinations should be made of the unfiltered river water, of the water as it issues from the filters, and of the water in the wells and mains and generally that the examination of the water should be placed upon a more scientific and systematic footing.

In the light of this report the Board considered it necessary to appoint a permanent officer to control the examination of the water and in July, 1905, appointed Dr. Alexander Cruickshank Houston (later Sir Alexander Houston) as the first Director of Water Examination (see p. 46).

After a further survey of available properties that the Board had inherited from the companies the premises at No. 20,

Nottingham Place, W.1, were fitted out as a laboratory and a staff consisting of two chemists, two bacteriologists, two laboratory assistants, two clerks, six collectors of samples and three laboratory boys was appointed in September, 1905. The organisation was put to a successful test on 25th October, when Dr. Houston started to make a systematic daily examination of the filtered water. By 1st November, the department's operations had extended so as to cover the whole of the examinations proposed to be undertaken, leaving the question of research work to be gone into more thoroughly at a later period.

During the first six months ended 30th April, 1906, 5,533 samples of water were examined either chemically or bacteriologically, exclusive of 309 samples collected for special purposes. Examinations undertaken in previous years by Professors Crookes and Dewar had risen from 6,731 in 1900 to 9,146 in 1904. An idea of the way in which examinations have increased during the period under review can be obtained from the following tables showing the number of samples examined in different years:

Year	*Chemical*	*Bacteriological*	*Total*
1920–21 ...	3,617	9,232	12,849*
1930 ...	4,433	11,261	15,694*
1939 ...	5,713	30,579	36,292
1946 ...	12,493	38,925	51,418
1949 ...	13,057	45,182	58,239
1951 ...	10,985	42,454	53,439

* Excluding a large number of samples examined for special purposes.

In addition to the above the following samples have also been examined for taste or other reasons:

Year	*Taste*	*Miscellaneous*	*Final Total*
1939 ...	12,381	4,244	52,917
1946 ...	6,198	19,343	76,959
1949 ...	9,652	24,394	92,285
1951 ...	9,716	22,015	85,170

In June, 1906, the Board decided to inaugurate research work with a view to ascertaining, to a greater degree than was then practicable, the effects of storage and filtration on raw river waters. The necessary expenditure for extending the laboratory and for the additional equipment was therefore sanctioned

and Dr. Houston's staff was also increased in order that he might devote proper time to this work. Since this decision was taken research work has formed an integral part of the duties of the Water Examination department and the results have been published from time to time. Thirteen research reports prepared by Dr. Houston were published by the Board separately between 1908 and 1920. Subsequent reports on research have appeared in the Director's Annual Reports. These reports have not only exerted a strong influence on the Board's policy in the construction of new works and the administration of existing works, but have also had a widespread influence, both in England and abroad.

The New Laboratories

Although the premises at Nottingham Place had been adapted for the purposes of a laboratory they were never really suitable and this fact became more apparent in the course of years as the work of the department expanded. Consequently, in 1936, Mr. J. Murray Easton, F.R.I.B.A., of Stanley Hall & Easton and Robertson, the architect of the Zoological Laboratories at Cambridge, was engaged to prepare a preliminary scheme for the construction of the new Laboratories.

In order to obtain first hand information of the latest developments in modern laboratory construction and practice, Lt.-Col. C. H. H. Harold, the second Director of Water Examination, visited America with Mr. Murray Easton in September, 1936.

Mr. Murray Easton then prepared drawings and estimates which represented the building as we now see it at New River Head. The layout was determined by the necessity for a north and south aspect and for erecting it as far as possible from traffic. The opportunity was also taken of incorporating an agreeable garden layout to enhance the simple character of the building. The curved form adopted by the architect has several advantages. It has the effect of linking up with the existing Head Office building (the quadrant would, if produced, strike the end of these at right angles). It also provides some 30 feet more window space for the laboratories, all of which face the north light, and this is a distinct advantage. The building itself contains two complete floors and a basement, with a set of rooms

forming an additional storey on the north side only, served by a corridor running the whole length of the block. This arrangement has the advantage that an additional set of rooms could be erected on the south side of the corridor. The building is so arranged that intercommunicating groups of rooms are provided for various purposes. A special system of air conditioning serves the first floor where atmospheric impurities would be particularly undesirable.

Colonel Harold devoted much time and labour to the planning of the laboratories and his insistence on every detail being provided for before the building was erected is largely responsible for the fact that after fourteen years' experience none but the most minor alterations have been required. The building, which was opened on 17th October, 1938, by the then Minister of Health, the Right Honourable Walter Elliot, M.C., M.P., remains as a lasting monument to the energies of Colonel Harold whose untimely death occurred a short time before the building was completed.

Present functions of the department

The control of the quality of the water is exercised from the Board's laboratories at New River Head under the personal supervision of the Director of Water Examination, Lt.-Col. E. F. W. Mackenzie, who was appointed in 1939. The department is divided into five main sections; namely, biological, bacteriological, chemical, works chlorination and administrative. The total staff in 1952 was seventy.

The biological section includes a qualified biologist and a qualified assistant biologist together with a laboratory assistant, and is concerned chiefly with the condition of reservoirs and rivers. Much of the work is out of doors and consists of periodical surveys together with supervision of special chemical treatment applied to reservoirs.

The bacteriological section includes four qualified bacteriologists in a staff of sixteen and is concerned chiefly with the safety of the water and with improvement in bacterial quality as it passes through the various purification processes.

The chemical section includes three qualified chemists in a staff of eight and is concerned with the examination of the chemical and physical quality of the water including clarity,

colour and the detection of tastes. A works chemist is in charge of twelve chlorination supervisors and assistants whose duties are to ensure the efficient working of the chemical treatment apparatus on the works and to carry out large scale disinfection processes.

The collection of samples is carried out by sample collectors who are provided with motor vans for the speedy transit of samples to the laboratories.

A more detailed account of these various functions will be found on page 271 *et seq.*

CHAPTER XXII

Purification

Protection of Sources

In safeguarding the purity of any supply of water the first and obvious measure is to ensure that as far as possible the source is protected from pollution. The degree to which this precept can be followed varies with the nature of the supply. It is mentioned elsewhere that by far the greater part of the Board's supply is obtained from the rivers Thames and Lee; the remainder is drawn from underground. These two rivers receive a number of discharges of sewage and other effluents and while the Thames is large enough to neutralise the effect of this pollution the Lee has required the most careful attention to prevent its being overwhelmed.

The greater problem thus lies with the Lee. It is not a large river and its valley has in recent years been subject to considerable residential and industrial development which has had a most serious influence upon the suitability of the river water as a source for a domestic supply. The proposal some years ago to site four satellite towns at Stevenage, Harlow, Welwyn and Hatfield—all within the catchment of the River Lee—gave rise to grave apprehension. When these towns were first mooted it was foreseen that special measures would be necessary if the river were to be preserved as a source of London's drinking water. Prolonged negotiations ensued between the Ministry and the several interested authorities and as a result of the Board's representations a central scheme of sewage disposal to receive the discharges from these and possibly other towns was agreed and is already fast taking shape near Ware in Hertfordshire. Not only will the effluent be of a high standard of quality, but it will be absorbed as far as is practicable in gravel deposits in that area so that the river valley will not be deprived of the water. The local circumstances are such that this can be achieved without detriment to the quality of the underground water. If successful, this method of disposing of the effluent will

obviate the need for constructing many miles of outfall sewer at great cost. It will also be an interesting experiment which may create a most valuable precedent. It has been agreed that should this method of disposing of the effluent into the gravel beds prove unsuccessful, a pipe will be laid to carry it to a point on the river below the Board's intakes.

Moreover, a new factor has obtruded itself upon this aspect of water conservation. Recently publicity has been given in the daily press to masses of foam which form from time to time in the upper waters of the River Lee as a result of the increasing use of soap substitutes which are not destroyed in the sewage purification works. It requires little stretching of the imagination to visualise what might be the condition of the river were it required to receive the effluents of these new towns in addition to the existing population of the catchment and there is as yet no reason to believe that these substances are removed by water purification processes.

Smaller schemes of rehousing and normal development have had to be considered from time to time and by treating each case on its own merits it has nearly always been possible to ensure that the river would not suffer.

Protective measures for the Board's wells are in a different category altogether. These wells are spread over a large area principally in Kent and with certain exceptions they yield water of the highest quality. It is impossible to define the area from which any particular well receives its water by soakage of rain into the ground and it is equally impossible, even were it desirable, to control the activities of life over a large area of country to ensure that no pollutive matter enters the ground. At the same time it is to be remembered that many of these wells are sunk into the chalk which is not a continuous but a fissured formation and with this fact in view all practicable steps are taken to ensure that ill-considered development does not take place in their vicinity. In built-up areas such considerations have to be viewed in a different light and the danger of sudden pollution has to be countered by extra protective measures in the scheme of water purification and examination. A particular instance of such a case will be described later. Meanwhile it may be mentioned that in the Water Act, 1945, it is laid down that the sinking of wells in certain areas including that of

London is not to be undertaken except under licence. The Board's interests are thereby protected.

Purification of the Board's Supplies

Water is purified in a number of ways according to its special characteristics and the nature of its impurities or pollution. It is easily understood that the measures applied to organically pure, colourless and clear well water are different from those adopted for polluted, coloured and possibly turbid river waters. The Board enjoys both sorts of supply. The treatment of the wells will be described in more detail later, but in short it consists of chlorination to destroy undesirable bacteria and subsequent removal of the excess of chlorine when it has done its work. Treatment of the river waters is not so simple. In the descriptions which follow, some emphasis will be laid upon the steps which over the last fifty years have resulted in present day practice.

The river-derived water is purified by three successive stages of treatment in the following order, namely, Storage ; Filtration ; Chlorination. The first two are dealt with in this chapter. Chlorination, which is of special interest in the present context, is described in detail in the next chapter.

Storage

The storage reservoirs which the Board inherited had been built partly to provide a reserve of water against times of insufficient flow in the rivers, and partly to avoid the use of flood water. They also permit the sedimentation of suspended matter which occurs when water is retained in them. In the last decade of the nineteenth century, Professor Frankland had demonstrated the bacteriological improvement consequent upon the storage of polluted water and this work was later confirmed and extended by Dr. Houston.

The relation of storage to the quality of water had begun to attract some attention at the beginning of the present century although storage was still regarded more as an indispensable asset against drought than as an aid to purification. How true this was may be judged from the case of the Staines storage reservoirs. These two reservoirs, capable together of holding over 3,000 million gallons, had their inlets and outlets arranged

in the same towers, circulation of water through them being therefore impossible. It is clear that they were designed not for the continuous supply of river water purified by slow circulation through them, but purely as storage basins to be used only in case of drought or when the river was in flood, or as compensation water. On the appointed day, therefore, the position was that a population of over six million persons was being supplied with water, about 80 per cent. of which was derived from rivers admittedly sewage-polluted, while the storage reservoirs were mainly lying idle. No inconsiderable proportion of the total supply from the Thames was thus run on to the filters in either a raw or, at all events, in an inadequately stored condition. In December, 1904, the Staines reservoirs were brought into active use for supplying the works of the West Middlesex district and in March, 1905, for supplying, in addition, those of the Grand Junction district. The improvement in the quality of the water delivered from these works was attributed by the Water Examiner to the stored water from the reservoirs.

The circulation in the Staines reservoirs was partly remedied by the introduction of syphon pipes between the two reservoirs in 1907. This enabled the raw water to be pumped into the North reservoir and the stored water to be drawn from the South reservoir and this promoted a certain amount of circulation.

At this stage may be added a short explanation of the terms in which the bacteriological quality of water is assessed. Many diseases are caused by minute organisms called bacteria and a few of these diseases, notably cholera, typhoid fever and dysentery in this country, are capable of being spread by water. These diseases are therefore called "water-borne." One of the chief duties of the water bacteriologist is to determine whether a sample of water is likely to contain any germs of disease. It may be difficult to find these germs as they are generally present in water in relatively small numbers and might be entirely absent from the amount contained in a sample bottle, yet present in the bulk of the water in sufficient numbers to produce disease in a susceptible person. Furthermore, if the purity of water were to be judged upon the finding of germs of disease, and action were to be delayed until their presence in the water could be

proved, the damage would have been done before preventive action could be taken. Their presence must, therefore, be forestalled, and for this purpose an indication is required not of the presence of disease germs, but of the possibility that they might be present in the water. Fortunately a germ exists in polluted water which provides the necessary indication. Human and animal excrement contains countless millions of a particular kind of germ known as *Bacterium coli* (*Bact. coli*). It also happens that for every disease germ which may be present in sewage there is also present a very much larger number of *Bact. coli*. Now, whereas it is not easy to find disease germs in water containing them, it is a comparatively simple task to find the accompanying *Bact. coli*. The germs of the water-borne diseases die in water more quickly than *Bact. coli*, so that when the water examiner has shown that a sample of water contains no *Bact. coli* he is safe in saying that it contains no dangerous germs. *Bact. coli* is therefore the germ upon which he fastens his attention. If it is absent he knows that the water is free from the germs of disease, while if it is present in appreciable numbers he views the water with suspicion.

Among the advantages that Dr. Houston found to accrue from storage were the following:

(1) Storage, if sufficiently prolonged, devitalises any microbes of water-borne disease which may be present.
(2) It greatly reduces the number of *Bact. coli*.
(3) It reduces the number of bacteria of all sorts.
(4) It reduces the amount of suspended matter, the colour, and, to a slight extent, the hardness.
(5) It has a marked "levelling" effect on the quality of water delivered to the filter beds; any water of indifferent quality becomes diluted with good water.
(6) The removal of suspended matter by sedimentation reduces the work of the filters.
(7) The use of adequately stored water reduces the risk from any accidental breakdown in the filtering arrangements.

Storage, while being a most important factor in increasing the "safety" of a water, is not without its attendant difficulties and drawbacks. For one thing the question of cost cannot be avoided. Most of the Board's reservoirs are so placed that it is necessary to pump water into them. If the reservoirs are to be

used actively, that is with water being continuously circulated through them, pumping charges are a constant item.

From the standpoint of water quality, however, the drawback of storage is a biological one and serious difficulties have arisen on a number of occasions in the Board's history. The waters of the Thames and Lee are both fairly rich in bicarbonate, are slightly alkaline and contain organic impurities. These conditions together encourage the growth of algae and kindred organisms which at times have developed to such a degree that the water has become coloured and turbid and has possessed an unpleasant taste. The organisms themselves have sometimes so impeded filtration that it has been difficult to operate the filters.

In 1907, the development of algae in the Staines reservoirs was continued at Barnes and reached such a concentration that the filter beds at these works looked as though they had been fouled with green paint. In this case copper sulphate was successfully applied. In 1913, an excessive development of other forms at Staines was augmented by re-storage at Barnes and this time resulted in complaints of taste from consumers who compared the water to rotten fish and castor oil. On both these occasions the suffragettes are said to have been blamed for the troubles.

In 1936, Queen Mary reservoir was afflicted and the operation of the Kempton Park works was maintained only with difficulty. Other less notable outbreaks have also occurred in various reservoirs from time to time.

In 1935, the biological section of the Water Examination department was formed in order that the biological behaviour of the Board's waters might be studied with a view to overcoming these very real difficulties.

Some very interesting and indeed far-reaching conclusions have been formed in connection with the biological behaviour of bodies of water such as those represented by the Board's storage reservoirs. Behaviour is often individual to a particular reservoir and the algae which flourish in one are not necessarily present at the same time, if at all, in another. Very often indeed they bear little relation to the algae present in the river water itself at the time of its abstraction.

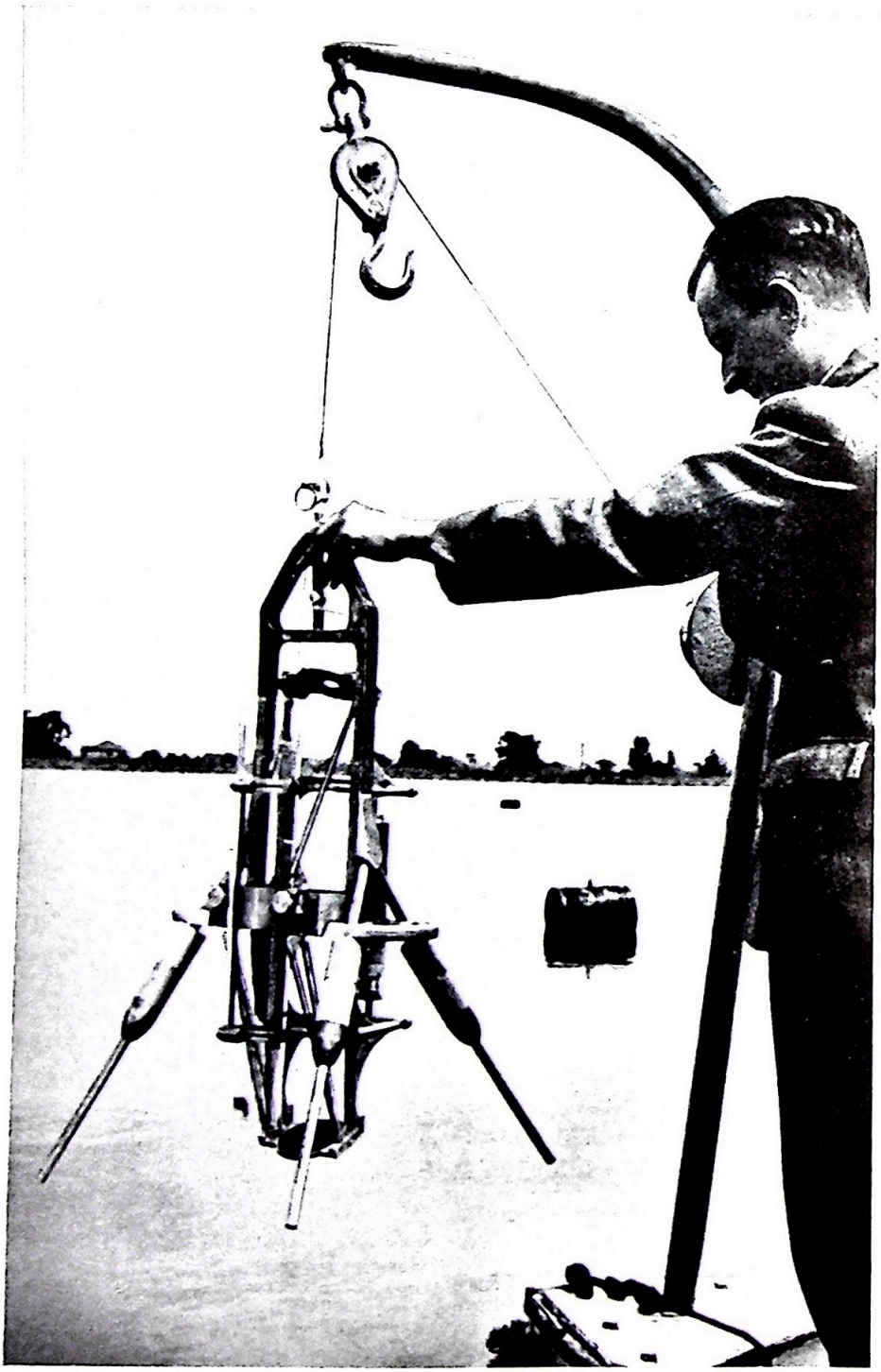
The algae introduced when river water enters such a reservoir tend to die and their remains sink to the bottom and so provide a reserve of nutrient for other growths as decomposition proceeds. Other growths tend thus to be supported, drawing their supply of food from the water. In the absence of restrictive measures such reservoir growths attain a maximum when, faced with unfavourable conditions, notably the exhaustion of an essential substance from the water, they, too, die and sink to the bottom, thereby increasing the store of nutrient in the bottom mud. Meanwhile, yet other algae, types with different food requirements, make their appearance and as time goes on the reservoir becomes increasingly fertile.

The depth of reservoirs has also been found to be significant in relation to the quality of the stored water. Thermal stratification tends to take place if the water is appreciably more than about 30 feet deep, and once the oxygen in the lower layer has been used up by decaying growths, putrefaction in the bottom mud sets in, with the resultant release to the water of odoriferous substances. When seasonal changes of temperature or gales of wind upset the state of thermal stratification the lower foul water becomes mixed uniformly throughout the body of water and the whole may be rendered unusable for the time being. This happened with the Queen Mary reservoir in 1935.

In the design of new reservoirs care is taken to avoid these pitfalls by ensuring that inlets and outlets are so arranged that water is uniformly displaced throughout the reservoir, by arranging the retention period, if possible, so that "river" algae die out without allowing "reservoir" algae to become established, and by not having the water deep enough for appreciable thermal stratification to take place.

With existing reservoirs preventive measures are adopted in so far as they are applicable. The principal measure with the larger reservoirs is that of applying a small dose of copper sulphate to the water when a growth is in the ascendancy. This is done by patrolling up and down the reservoir in a motor vessel and dosing the chemical as evenly as possible over the whole surface. Not only is the growth itself checked, but the nutrients which the organisms would otherwise have abstracted from the water (to be later returned to the bottom when the algae die) are swept out of the reservoir by the flow through it.

AMPHIBIOUS VEHICLE ADAPTED FOR THE CHEMICAL TREATMENT OF RESERVOIRS



A "JENKINS" MUD SAMPLER

This apparatus cuts a core of mud from the bottom of the reservoir and brings it to the surface for examination

With smaller reservoirs considerable success has been obtained with intermittent low doses of chlorine applied at the inlet. Growths are thereby checked while, by the intermittency of the treatment, other and chlorine-resistant forms are not permitted to develop.

In all this work success is obtained only by the most constant inspection, together with frequent biological and chemical examinations of the water backed by an accumulation through the years of scientific knowledge and local biological data.

The success attending the work of the Water Examination department has progressively increased with the accumulation of knowledge since the inception of the biological section. As a result of their operations afflictions of the nature previously described are now hardly to be feared. This improvement in the quality of the reservoir water has, moreover, been accompanied by a great increase in the algal growths in the river which now carries massive crops of a particularly troublesome diatom for a great part of the year. The consequence of this improvement on the one hand and deterioration on the other has been that it is now seldom advantageous to pass unstored river water directly to the filters.

Filtration

At their inception the Board acquired upwards of one hundred open slow sand filters, each about an acre in area. Many of these had already been in use for some decades, quite a number of them having been built in the middle of the nineteenth century as a consequence of the Metropolis Water Act of 1852, which required that all river-derived water for London be filtered.

During the period following immediately upon the first World War, the Board were faced with demands for more water and were therefore in a position either of having to install more slow sand filters or of devising means whereby the existing filters could produce more water without deterioration in its quality. Various arrangements of two-stage filtration had in the foregoing years been used by others and with these in view the then Director instituted experiments within the Board in which stored water was passed through rapid filters prior to its being filtered at a faster rate than normally through the slow sand

filters. These experiments showed that the scheme was practicable with the Board's particular waters. By using primary sand filters, operated under gravity and without a coagulant at a rate of filtration of somewhat over one hundred gallons per square foot per hour, followed by filtration through the slow sand beds at about double the old rate of two gallons per square foot per hour, water of the established standards of chemical and physical quality was consistently produced. A qualification was nevertheless introduced in that the more rapid treatment did not provide quite as efficient a barrier against the passage of bacteria. As, however, by this time chlorination had become an integral part of water treatment in the Board this disadvantage did not possess the significance that it formerly would have done.

The experiments having clearly demonstrated that the output of an installation of slow sand filters could be doubled at relatively small cost, with the adjunct of primary filters, the Board embarked on a policy of installing them at various works as the demands for water increased. The first were built at Barn Elms and were put to work in 1923. Walton was equipped in 1926, Kempton Park in 1929, Stoke Newington in 1936 and Hampton during the last war, the first of the new filters here being put into operation in 1941.

In general terms primary filters remove the coarser suspended matter from the stored water and so relieve the slow sand, or secondary, filters. The water is rendered less turbid and its colour is slightly reduced. An addition to these physical improvements, however, is the removal of ammonia. Rivers such as the Thames and Lee are never entirely free from ammonia, as a legacy of the sewage and other pollutions to which they are subject, and ammonia has an undesirable effect upon the efficacy of chlorination. It is notable that, despite the high rate of filtration and the consequent short interval of time during which the water is in contact with the filtering sand, primary filtration removes ammonia. The sand bed quickly becomes colonised by nitrogen-oxidising bacteria which act upon ammonia and the filtered water is virtually free from this substance.

In considering their reconstruction programme after the last war the Board were naturally subject to the difficulties occasioned by the general shortage of raw materials and

accordingly turned their attention to the clarification of water by means less expensive than primary filtration. Many years ago some experiments had been undertaken with a rotary strainer and this piece of apparatus was brought to mind at the time when the subject of primary clarification was being reconsidered. The makers of the strainer were approached with a request for a larger model to be fitted with the finest possible gauge wire mesh. For various reasons it was not possible at that time to install such equipment at a works equipped with primary filters where it would have been possible to conduct comparative experiments. The new strainer was accordingly fitted at the Surbiton works, the strained water being filtered through a slow sand bed worked at a higher rate than normally. Sufficient data were accumulated to suggest that its performance might be expected to compare, although somewhat unfavourably, with primary filtration with, of course, the exception that the strainer merely removed particulate matter and produced no chemical change whatever in the water.

By this time it was possible to extend the experiments on a larger scale at the Kempton Park works where a direct comparison with primary filters could be made. A battery of four strainers was therefore erected at that works and stored water led to them, the strained water being subsequently filtered through two secondary filters separated for the purpose from the normal dual filtration scheme.

This work was continued for some five years and a large body of information was obtained. With the qualification already mentioned that strainers do not bring about any chemical improvement of the water it may be said that they have been found to be about two-thirds as efficient as rapid filters.

With all points of view taken into consideration, not least among them being the relatively small quantity of steel and other materials required for their construction and the relative facility of their supply and erection, it was decided to install rotary strainers instead of primary filters at Lee Bridge and at the new Ashford Common works.

The Board have up to the present adhered to slow sand filtration performed very much in the same manner as that instituted by Simpson at the Chelsea Waterworks in 1829. The modifications to the method have been principally the already

described adoption of primary filtration—and the move towards the alternative measure of micro-straining—and, secondly, details of layout and construction designed to protect the unfiltered and the filtered water from subsequent contamination. For example, the concrete surroundings of filters now slope away from instead of into the bed, so that bird excrement and other impurities are not washed in by rain. The filter wells and engine suction wells are protected by adequate sills and properly designed covers to the same end. Again, the filters were originally built at low levels so that river water could flow on to them by gravity. Consequently much of their structure was below the standing level of the ground water at the site. Neither brick nor concrete structures of the type in question can be expected to remain watertight indefinitely, and ground water, possibly polluted, can be expected to find its way in when the beds are drawn down for cleaning or other purposes. The filtered water channels and the filtered water wells are thus prone to pollution. Such hazards constitute perhaps the weakest feature in purification by slow sand filters.

With the most recently constructed beds, as at Walton and Ashford Common, these and other defects have been avoided by building at higher levels and paying the maximum attention to measures for protecting the water from pollution at all stages in its passage through the works.

Despite these modifications, the adherence of the Board to the original principle of filtration even up to date does not in the least imply that the method is regarded as being necessarily the best for the Board's particular purposes. Other methods of water purification have, as is well known, been developed during the present century and the Board have not only kept abreast of developments but have for some twenty years been conducting experiments of their own to determine the applicability of the recent chemical methods to the clarification of their stored river waters.

At the risk of insistence it must be made clear that the difficulties of purification presented by the Board's stored waters, while not being unique, are inherent in the geology of southern England and in the fertility of the waters of the Thames and the Lee. In short, these waters are very prone to the development of algae, especially upon storage. In more norther-

ly districts where the water is naturally soft and slightly acid, algal development is not pronounced and the problems involved are different in character.

The later method consists essentially of adding to the unpurified water a small quantity of a soluble chemical substance—or a mixture of substances—whose nature is to combine with mineral constituents naturally present in the water and, as a result, to be thrown out of solution as a flocculent mass which enmeshes suspended impurities and, after sedimentation, leaves the water clear. The clarified water is then filtered rapidly and the filtrate, except for considerations of disinfection, is ready for supply. The substance most used for this purpose is aluminium sulphate, generally called alum—though not quite correctly—while salts of iron are sometimes employed. The process of separation of the chemical and the most finely divided suspended impurities is called coagulation and the substances used are termed coagulants.

At first sight it may appear a simple process and one applicable to any water possessing the appropriate mineral characteristics. Unfortunately this is not the case for while with the Board's water it is easy enough to cause the coagulants to form a "floc" and at the same time to enmesh inert suspended matter, it is very difficult to trap algae.

Experiments were continued at intervals throughout the nineteen-thirties, both in the laboratory and with pilot plant at Barn Elms works in order to arrive at a method which would at all times clarify stored Thames water. A certain hiatus was created by the outbreak of war but the work was restarted in 1943 using somewhat different principles of operation from those tried hitherto. The treated water was caused to flow slowly upwards through a vessel at a rate which did not preclude the settlement of the floc against the current, whereas formerly it had flowed horizontally across a tank with the floc slowly settling to the bottom. In the newer method the incoming treated water had all to pass through a zone or "blanket" of previously formed floc and this tended to facilitate the separation of the fresh floc. The experimental plant was removed to Hampton where a variety of sources of water could be led to it, and encouraging results were obtained. The next development was the temporary alteration, in 1945, of two of the primary

filters at Barn Elms to permit of their use as upward flow clarifiers and the process was tried on a works scale. Although good results were obtained with it, the adapted plant did not permit of more than tentative work and it was clear that it would be necessary to construct full scale experimental plant if the possibilities of the coagulation process were to be fairly assessed. A résumé of the Board's experiments and conclusions was therefore sent to a number of contractors who submitted proposals for full scale plant to be erected at Kempton Park.

Of the tenders received, three types of upward flow clarifiers and one tank for horizontal flow sedimentation were selected.

Work was begun at the new plant in May, 1950, since when much has been learned. A variety of algal conditions has been encountered and more than one coagulant has been tried. The nature of the work is such, however, that final conclusions will not be available for some time to come. All combinations of applicable chemical substances must be exploited to the full. Equally significant is our subservience to the vagaries of nature for it is beyond our control to command for our convenience the development of a succession of those algae with which the Board have in their fifty years been afflicted from time to time. Nevertheless, and despite the many failures of the past, our encounters with those which have so far appeared have not been entirely discouraging.

CHAPTER XXIII

Chlorination

We live in an age of development. On all sides we are confronted by examples of the development over many years of basic ideas into forms which bear little resemblance to the original. What is more, they have become accepted as parts of the pattern of life and are no longer regarded with wonder, mistrust or whatever other feelings were called forth on their first appearance. It is a far cry from the "horseless carriages" of the eighteen-nineties to the speedy, comfortable and safe cars of today; from the early wireless telegraph to the television sets with which we, at ease in our homes, can watch events actually taking place far away. To the workers in a particular field progress often seems slow, and it is only by stopping to compare the stage at the moment with what it had been a number of years before, that it is realised that a lot of progress has indeed been made.

The present account is concerned with the development of chlorination, more particularly as far as it has been applied to London's water supply, and this subject is no exception to the above generalisation. To some it may appear that there is little difference in principle between the present method and that practised in the early days. This is true up to a point. Chlorine was added to the water then and it is added now. The difference lies largely in the greater understanding of the reactions involved and in the consequent ability to avoid the ill effects of the many complicating factors. It would be pleasant to be able to state that chlorination in this country started within the Board, but although this cannot be claimed, it is a fact that one of the two directors of its first application was Dr. Houston and that he was assisted by Mr. D. B. Byles at Lincoln in 1905, shortly before their entry into the Board's service. In view of this connection, it is felt that it would not be trespassing too flagrantly to use this incident as the starting point of the Board's story.

An outbreak of water-borne typhoid began in December, 1904, at Lincoln where the supply was drawn from a river and filtered through slow sand beds. Drs. Houston and McGowan were called in to investigate the matter and to install measures to establish a pure supply. The former was responsible for the bacteriological work and the latter undertook the chemical work. As their assistant they chose Mr. D. B. Byles. It was mentioned above that this was the first occasion, at least in this country, of the continuous application of chlorine to safeguard the purity of a water supply. The workers, therefore, had little to guide them apart from the knowledge that very small doses of substances containing available chlorine exerted a marked bactericidal effect in water. They erected a simple and, in our present view, rather crude apparatus to administer a small dose of a proprietary solution known as Chloros to the water as it flowed through the Lincoln works. Unfortunately the negative of the snapshot which was taken of the operation has long since been lost but the illustration entitled "Dawn of Chlorination" (facing p. 256), shows a reproduction of a print which has survived. The Chloros was contained in the stone jars and was run at a controlled rate into the water being treated. The supply was rendered free from typhoid bacteria and the epidemic ceased.

Dr. Houston became the Board's first Director of Water Examination in 1905. Mr. Byles joined the staff of the Water Examination department later in the same year and until his retirement as deputy director in 1945, was the officer most closely connected with the actual chlorination of the Board's supply.

Although the water from Rye Common well had been chlorinated in 1910, the Board first applied chlorination treatment to river water in 1916. For some years previously they had, on Dr. Houston's advice, followed the policy of passing all river-derived water through one or more of the storage reservoirs, before filtration, in order to promote the death of the disease-producing bacteria which such water is prone to contain. By 1916, however, the coal necessary to pump the water into the reservoirs was required so insistently for other purposes of national importance and was so costly that Dr. Houston declared himself willing to forego the bacterio-

logical safeguard of storage and to countenance the filtration of water straight from the Thames on condition that it were chlorinated on its way to the filters.

In view of the large volume of water to be treated—some 75 million gallons a day—it was decided to use not Chloros but bleaching powder as this contains about one-third as against about one-tenth of its weight of available chlorine and was generally more appropriate to the purpose in view. A system of tanks was therefore set up at Staines to prepare a solution of chlorine from bleaching powder to treat the water flowing down the Staines aqueduct. Treatment at this point was maintained for several years and was finally discontinued as chlorination was extended to other parts of the Board's works.

This was the era of what has aptly been called "marginal" chlorination. Beyond the fact that a very small or marginal dose of chlorine—a fraction of one part in a million—gave as much bacteriological improvement to the water as weeks of storage, very little was known of the mechanism of the process. It should be noted that it was performed before filtration (hence "prechlorination").

Water such as that from the Thames is a composite of a large number of substances other than the water itself. Some of these are mineral and are always associated with that water by virtue of the geological nature of the area of country which contributes to the flow in the river. Others are adventitious and comprise such a variety that it would be difficult to catalogue them. These substances together with countless bacteria find their way into the river mainly from sewage and other effluents and from the general drainage of the catchment area. Some of the forms are indeed produced within the river itself, for a river is a biological association, and procreation, digestion, death and decay are going on within it all the time. The point to be made about these constituents is that they are present only in terms of parts per million parts of water. Many of them which have a bearing on chlorination are present in only fractions of one part in a million.

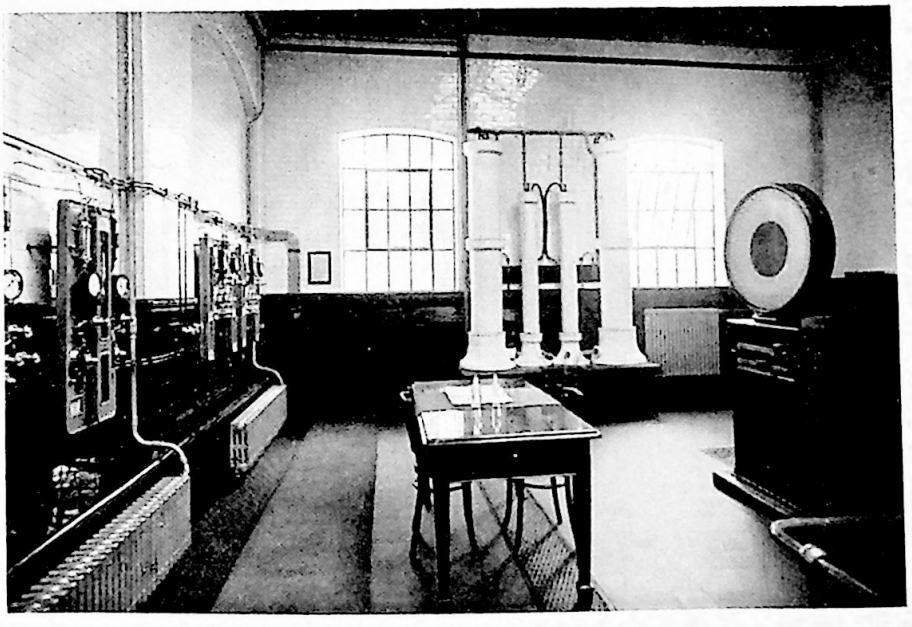
This prechlorination was instituted rather as a matter of economy than as a measure for increasing the safety of the water. Dr. Houston was, however, well aware of the potentiality of chlorine for the latter purpose and he experimented

in its use for sterilizing the water after filtration. In this, however, he was not at first successful and the experiments had to be abandoned owing to the occurrence of objectionable chlorine-induced tastes.

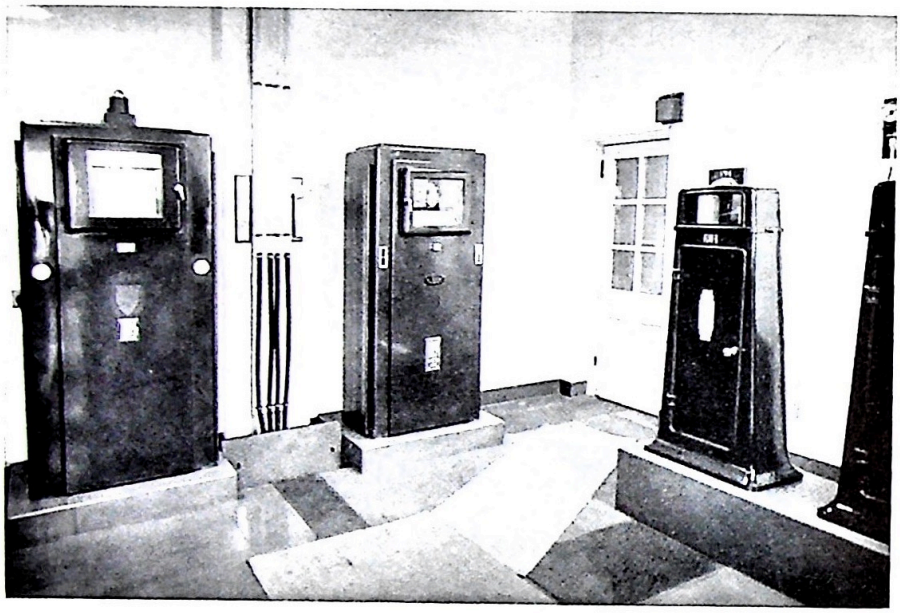
Towards the end of the first World War, Race in Canada had introduced a modification which influenced water chlorination for many years. He added ammonia to the water before the chlorine. The claims made for ammonia-chlorine or chloramine treatment were that it was less likely to impart taste to the water, that it persisted in the water for a longer time than did chlorine alone and that it was a more active disinfectant. There was a certain amount of truth in these claims and chloramine treatment can be used with advantage in certain circumstances. At the same time it must be remembered that the reactions which take place in water with the extremely small concentrations of naturally occurring substances and added chemicals were not understood when chloramine was introduced and, as events have shown, the implications of the observed results could not be assessed in their true perspective.

Dr. Houston found that the worst of the tastes which had been imparted to the water by marginal doses of chlorine did not arise if the water contained a sufficiency of ammonia to form chloramine. He therefore discontinued his experiments in the use of marginal chlorination for terminal sterilization, and used chloramine for the first time at the Walton works in 1928. For this purpose he added first ammonia and then chlorine. The ammonia was applied as a solution of ammonium sulphate, the chlorine being derived from bleaching powder. Bleaching powder as the source of chlorine gave way to chlorine gas bought in the liquefied form in steel containers and dispensed by apparatus which measured the flow of gas, then caused it to become dissolved in a small supply of water and finally injected the solution at the point where the treatment was required. In course of time, as in the case of chlorine, ammonium sulphate solutions tended to be replaced by ammonia gas applied through special apparatus. At the moment it will suffice to say concerning the Board that chloramine treatment was practised for a number of years for the final purification of its river-derived filtered waters.

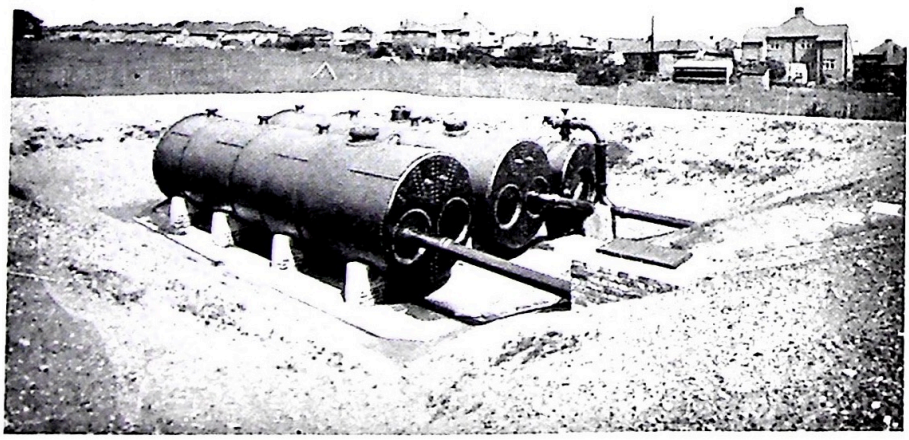
DAWN OF CHLORINATION
Lincoln chlorinating plant, 1905



CHLORINATION APPARATUS TWENTY YEARS AGO



MODERN CHLORINATION APPARATUS



BOILERS ADAPTED FOR USE AS CONTACT TANKS
AT NORTH ORPINGTON

The Board suffered the loss of Sir Alexander Houston in 1933 and of Lt.-Col. C. H. H. Harold, his successor, who had been an ardent advocate of chloramine, in 1938.

The present Director, Lt.-Col. E. F. W. Mackenzie, O.B.E., M.C., M.B., Ch.B., D.P.H., took office with the Board in the following year and it will not be out of place at this stage to mention some work which he carried out in India in 1932 at a time when the chloramine process was in its heyday.

Little was known of the reactions which occurred in water with the combination of ammonia and chlorine, but it was known, or at least postulated, that one or more of these different compounds, namely mono-chloramine, dichloramine, nitrogen trichloride and possibly other products, could be formed. There was, however, no method available at that time for differentiating between these substances in very dilute solutions or of distinguishing them, together or singly, from free chlorine itself. The Indian experiments were directed towards an examination of the claims made for chloramine as regards its being a more potent bactericide than chlorine and that it did not produce taste. In the first place it was found that free chlorine was rapidly destroyed by tropical sunlight whereas chloramine was not. This somewhat primitive method of differentiation between these substances facilitated the interpretation of the main experiments.

These experiments showed that the speed of disinfection of chlorine is much greater than that of chloramine, and also that there is a marked difference between the bactericidal power of freshly prepared chloramine and chloramine which has been allowed to stand for some time. Furthermore the effects observed on exposure to sunlight justified the belief, since confirmed, that the difference in behaviour between the fresh and the stale chloramine solutions was due to differing degrees of combination between the ammonia and the chlorine in the two cases, and that the higher activity possessed by the fresh solution was actually due to free chlorine before it had had time to combine with the ammonia, and not to the chloramine itself which was relatively inert.

These results conform to modern conception but were at variance with the accepted notions of the day. Nevertheless, they led their author to the firm conviction that the addition of

ammonia for the purpose of forming chloramine was an irrational procedure.

Viewed in retrospect it is easy now to see how the misconception arose concerning the merits of chloramine. It was asserted first that the treatment prevented the formation of taste in water. This, however, was only a half truth in that while chloramine does not as a rule promote taste, neither does it do anything towards removing taste already possessed by the water. This may be illustrated by reference to the Board's river-derived waters. These contain traces of a vast number of organic substances. Some of these impart taste of themselves—even if they are present in only infinitesimal concentrations—while others, tasteless themselves, form taste-producing compounds when united with chlorine. The first group, those with inherent taste, are neither made worse nor improved by chloramine for the chlorine in chloramine is not able to combine with the polluting substances and so produce taste or destroy it. The second group, mainly phenolic in character, are rendered harmless by the presence of ammonia, for which chlorine has a predilection. Thus chloramine is formed instead of chlor-phenols having pungent and offensive tastes. But the formation of chlor-phenols can just as readily be avoided without ammonia by adding a sufficiency of chlorine which by oxidation destroys the phenolic bodies.

The second assertion by the protagonists of chloramine that it persists longer in treated water than does chlorine is true, but this fact is of little account when that which persists is so lacking in activity. Some there were, indeed, who asserted that chloramine is a more rapid bactericide than is chlorine, but this is so patently untrue that it will not be considered in this discussion. In point of fact the rate of disinfection by "free" chlorine is many times that of chlorine united to ammonia in chloramine. Nevertheless, the use of chloramine for final purification considerably enhanced the bacterial purity of the water and provided a valuable stop-gap pending the achievement of a fuller understanding of the chlorination process.

In passing from a discussion of the second to that of the third era of chlorination we are forced to interfere with the chronology of developments. Reference must, it is felt, be made to observations by Dr. Houston which now appear to have

been made in advance of their time. A truth was glimpsed but not fully seen, a far-reaching development half perceived but discarded through failure to appreciate the significance of results. In his Twelfth Annual Report covering the year ending 31st March, 1918, he wrote:

> "By a super-dose is meant a dose in excess of what is actually required under more favourable working conditions. It is always best to provide for so prolonged a contact that . . . the active chlorine will have disappeared and the water at the same time have been sterilised."
>
> "It has sometimes been observed . . . that when working with minute doses of chlorine . . . a slight 'iodoform-like' taste develops. . . . On the other hand, no taste, unless perhaps the original taste, has ever been observed after *gross* chlorination and dechlorination. Hence, in certain cases, there may, *so far as taste is concerned*, be an advantage in heavily chlorinating a water and then dechlorinating it."

Dr. Houston had anticipated the third era only a year or two after the first had commenced. Had it been possible for enquiries to have been pursued a period of development extending over some twenty-five years might have been avoided.

It will be noticed that he referred to "super-chlorination" and described it as being a dose in excess of what was actually required—and by this he obviously meant required for disinfection. He then modified this implication, for he added that "there may, *so far as taste is concerned*, be an advantage in heavily chlorinating a water and then dechlorinating it." These points are stressed in the present discussion for the question of taste is an integral factor in deciding upon any form of treatment and further because it is felt that the term "super-chlorination" cannot be improved upon to denote that process in the development of which so much of the pioneer work has been performed by officers of the Metropolitan Water Board.

Mention has already been made of the present Director's work in the early nineteen-thirties in which he found reason to believe that such bactericidal power as is possessed by chloramine is due largely to the chlorine before it enters into combination with the ammonia. The work was continued a few years later when he investigated methods of purifying water supplies for the Army in the field for which the advent of mechanization had made speed of disinfection a first requirement. This work terminated in 1938 and showed that whereas the then standard

method of chloramination required a contact period of at least one hour it was possible to reduce this to fifteen minutes or less by employing superchlorination and dechlorination. Not only this, but of the waters examined—and these included even a duck pond and canal water—those which gave a taste with chloramine gave tasteless water with superchlorination and dechlorination. The methods then advocated were adopted by the Army prior to the outbreak of war.

The point has been made that progress in the earlier years towards an understanding of the reactions which occur in water when it is chlorinated was held up partly through the absence of laboratory methods for differentiating between the various combinations of chlorine. The sunlight method was useful, but did not give the whole picture. Without such tests superchlorination could not be applied to the Board's river-derived waters efficiently and economically. This lack of knowledge has now been rectified. By this it is not meant that the last word has been spoken on the subject, but rather that recent discoveries have gone far to increase our understanding of chlorination and to enable rational control of the process to be exercised.

The recent advances which have shed light on much that had been obscure have provided the means of accurate estimation of chlorine and the several combinations of chlorine with ammonia. There are now a number of such methods—they have been worked out on both sides of the Atlantic—and they enable a complete assay to be made on a sample of chlorinated water. For the purpose of the present discussion, however, it will suffice to say of them that they have shown that the test commonly used for estimating chlorine (orthotolidine) can also be used to differentiate between free and combined chlorine with a fair degree of accuracy.

Much of this work was going on during the second World War when the Board were fully occupied in maintaining an adequate and wholesome supply of water for the people of London under very trying conditions which are described elsewhere. It will be readily understood that neither the Director nor his staff had much time to devote to those developments which have since not only simplified treatment but which are giving to the Board's supply a record of purity higher than

ever before. Chloramine treatment was in use in 1939 and it was continued throughout the war and until increasing knowledge led to the successful adoption of superchlorination.

On the cessation of hostilities the Board were faced with a programme of reconstruction and modification without precedent in its history. Many of the works were in need of repair and nearly all had been built before the days of chemical disinfection. Chlorination was an adjunct rather than an integral part. No provision existed for the correct application of chemicals either on filtration works or at well stations and it was a matter of the greatest difficulty at some works to maintain even the fundamental requirement of proportional dosing. Works had been enlarged and altered over a number of years and the ramifications were so complex that the correct apportionment of dose was sometimes a matter of trial and error. Added to this, there was no provision for contact between the chlorine and the treated water, the treatment being applied just before the water was pumped to the district.

The Board began systematically to rationalise the layout of their works and to install contact tanks. The dosing itself was thereby simplified and the treatment was rendered more effective.

The third era of chlorination (superchlorination) began with the period of reconstruction and it will be as well, in describing it, to consider the filtration works and the well stations separately, for they are concerned with slightly differing principles.

The term "superchlorination" is adhered to rather than others which are current, partly because it was used by Dr. Houston when he so nearly anticipated this form of treatment, but mainly because it best describes what it is meant to describe.

The rivers Thames and Lee, from which the Board derive supplies, drain a large area of southern England. Each receives a number of sewage and other effluents along its course and in consequence these waters contain, as mentioned earlier, traces of a diversity of substances and ammonia is always present in some degree. Except in very cold weather, biological agencies in the sand of the primary and secondary filters bring about the virtual elimination of the ammonia, while suspended matter

and the majority of the bacteria are removed at the same time. The filtered water, then, contains some bacteria and an amount of dissolved organic matter which varies with varying conditions and both these items are concerned in any subsequent chlorination. The ammonia content of the filtered water is normally so very small that it plays no part in the chlorination process. The added chlorine is in the "free" state and bacteria are quickly killed, but the reaction between the chlorine and the organic matter in the water is more prolonged. The fall in residual chlorine is rapid at first and then becomes slower, the treatment being adjusted so that the chlorine is all consumed within a desired interval of time, say one hour. By this arrangement not all the organic matter is oxidised, the proportion so oxidised depending mainly upon the dose and the contact period available. The treatment is, in fact, not aimed at satisfying the whole of the chlorine demand of the water. To do so would require relatively large doses of chlorine and periods of contact so long as to be impracticable and is in any case unnecessary. The procedure may therefore be truly regarded as one of superchlorination and dechlorination in the sense that a dose of chlorine much in excess of that required for disinfection is employed; the dechlorination is self-induced.

In practice it is found that a dose of chlorine of the order of one part per million—it fluctuates above and below this figure as the chlorine-absorbing state of the water varies—yields a residual of say 0.3 to 0.4 parts per million some ten minutes after its application and that this residual is dissipated by the time the water leaves the contact tank, that is to say an hour or so later. In the gradual absorption of the initial excess of free chlorine those substances which with lower doses would have combined with chlorine and produced taste, seem instead to be oxidised. Any taste of chlorine *per se* does not arise for the chlorine is all used up in oxidising organic matter. All other tastes natural to the river waters or contributed by algal growths in the reservoirs are also eliminated with the exception of an earthy or mouldy taste which sometimes occurs in these river waters and is obdurate in the extreme; activated carbon is required for its removal. One other benefit remains to be mentioned. It is that this form of chlorination results in a reduction of colour in the water by as much as 30 to 40 per

cent. It may be added that this virtual elimination of taste and reduction in colour had not been experienced with chloramination.

It need hardly be said that considerable research on superchlorination was carried out in the laboratory before any trial on the works was undertaken. This work engendered confidence that superchlorination might be applied to the Board's river-derived filtered water as an experiment unlikely to come to an unhappy conclusion through the too disastrous production of objectionable tastes. It is, however, true that laboratory experiments cannot always be directly translated into full scale practice. Great caution was therefore observed both as regards the purity of the water and the avoidance of taste.

The Barnes works were selected for the first experiment because the filtered water from these works passes under the river to Hammersmith pumping station, thus allowing a contact period of about half an hour after which the water may be sampled before it passes into supply. Laboratory tests having indicated that one part per million of chlorine should sterilize the water and not produce taste, the ammonia treatment was suspended at Barnes and the chlorine dose adjusted. This change was effected in October, 1947, and while a few complaints of taste were received in the first few months of the treatment, slight adjustments of the dose of chlorine removed cause for criticism on this score without detracting from the efficiency of the treatment.

Hornsey provided a more severe test for superchlorination, as the water of the New River, which supplies these works, had always been found to be particularly prone to develop taste when treated with chlorine alone. The change from chloramination was made later in the same month of October, 1947, and was successful from the first.

Further vindication of superchlorination was obtained next at Lee Bridge where, at that time, water was pumped into supply by a number of pumps drawing from different parts of the works. In February, 1948, one set of pumps was accordingly supplied with superchlorinated water while the remainder continued to pump water treated with chloramine. Everything was satisfactory for several weeks when a severe outbreak of algae caused the water to exhibit an offensive "weedy" taste.

That treated by superchlorination was rather worse than the water treated with chloramine. Instead of reducing the superchlorination dose it was trebled to two parts per million and the weedy taste disappeared from that section of the output from the works. To be true, a slight chlorinous taste remained but this was quickly dissipated in the distribution system and no complaints were received from the consumers of that water.

Following upon these successes, superchlorination was extended to all the Board's filtration works and prechlorination, which had been necessary to correct the shortcomings of the chloramine process, was discontinued. The bacteriological and physical quality of the water leaving the works since the adoption of superchlorination has been higher than ever before and these improvements have been accomplished with a saving of over £12,000 a year in chemicals alone.

The development of treatment of the well waters has followed a rather different path, one dictated by arrangements of supply and by the character of the water. In the days before the works were remodelled and while small doses of chloramine were in vogue, it was usual to administer the ammonia into the well itself and the chlorine at the well head. With those wells which were equipped with only a single stage of pumping, both chemicals were applied into the well. Token doses only were permissible in the interests of taste and such security as existed really lay to a large extent in the original purity of the water delivered from most of the wells and in the frequency of their examination; though even in these daily analyses lay a danger, in that many of the wells could not be sampled before chlorination and results could therefore be misleading. In the control of water supplies, departures from the normal in characteristics of analysis are sometimes the herald of serious pollution. The ability to observe small changes in the bacteriological flora was lacking where those waters were treated in the well and pollution could not have been detected until it had become great enough to overcome the treatment provided.

Several considerations combined to influence the form of the remodelling of the Board's well stations. In the first place, the above drawback had to be corrected. It must be possible to sample each water in the untreated state and this meant that treatment had to be arranged to take place at ground level. As

it is difficult to inject chlorine solution reliably and continuously into water against high district pressure it was necessary to arrange the pumping in two stages—the first to lift the water to ground level and the second to pump it to the district, the chlorine being applied against the relatively low pressure obtaining between the two stages.

Secondly, a contact period had to be provided to ensure disinfection before the water left the works. In deciding upon the extent of this contact period regard was paid to the character of the water concerned. The Board's underground water derives from the chalk, is of a high degree of general organic purity and usually is as nearly as possible free from ammonia. The water has practically no chlorine demand. The chalk is, however, a highly fissured formation and the possibility of sudden pollution even from a considerable distance had to be faced, particularly in the more inhabited areas. A dose of one part per million of chlorine was therefore chosen with a contact period of twenty minutes, followed by dechlorination. Although such heavy treatment of usually pure water may have seemed an unnecessary extravagance it was felt that this would provide a sufficient barrier against sudden pollution in the interval between the advent of the pollution and its recognition by routine tests for residual chlorine and by the daily bacteriological analysis. It was considered to be a reasonable premium to pay for insurance against an undoubted risk.

It was decided to dechlorinate completely rather than partially, for extensive surveys in areas supplied with water containing, respectively, a small residual and none at all, had failed to demonstrate any bacteriological advantage with the former procedure.

The arrangement of the new and remodelled well stations is thus as follows. The first stage of pumping raises the water to ground level where a tap is provided for sampling in the untreated state. Chlorine solution is injected into the main downstream of this tap, and another is then provided for check sampling. The water then passes, under the residual pressure from the well pumps, through a series of contact tanks —either disused boiler-shells (see illustration facing p. 257) or standardised cylindrical tanks—of a total capacity such that the water is retained for twenty minutes at the maximum rate

of pumping. In the outlet main from these tanks are, in order, a sampling tap for assessing chlorine consumption through the contact period, a point of application of sulphur dioxide for dechlorination, and finally a tap for sampling after the completion of treatment. The water then passes to the high lift pumps and is pumped into supply bacteriologically pure and retaining to the full its pristine excellence as a beverage.

Complete vindication of this system has already been provided, notably on two separate occasions.

During the test pumping of a borehole sunk at North Orpington in Kent during the last war it was found that the bacteriological state of the water was not good. The pollution was not, however, of an order to condemn the site and the station was completed after the pattern described above. With regular pumping the quality of the water was found to be worse than it had been during the period of test pumping; furthermore, it was found to fluctuate in step with rainfall thus showing that surface water was gaining access to the well without adequate natural filtration. It may safely be said that in view of the increasingly urbanised nature of the surroundings and the known presence of cesspits, the supply could not formerly have been used without incurring the great expense of providing filtration plant. Instead the high degree of chlorination was coupled with certain mechanical and automatic safeguards and this barrier alone was considered to provide as complete protection as could be devised. The raw water always contains *Bact. coli*, yet throughout the years since the opening of the station the finally treated water has consistently been maintained at the highest level of bacteriological purity.

The other instance was more recent and was fraught with the gravest risk of a major epidemic. But for the measures which had but a short time previously been taken, a disaster would have been highly probable. A well station had yielded an unimpeachable supply of some three million gallons a day for a number of decades. Despite this fact the station had been placed high in the order of priority in the post-war reconstruction plan, because it was situated in a built-up area and was considered to be potentially unreliable, despite its good record. The reconstruction of the chlorination facilities had been completed by 30th January, 1949. Samples of the water drawn

before treatment on 4th April, 1950, showed evidence of heavy pollution. Investigation was immediately made and the water was diverted to waste pending further examinations, pumping being continued. In the subsequent investigation it was found that the water in the well ultimately became polluted to a degree representing, on both chemical and bacteriological bases, one volume of sewage in about 150 to 200 volumes of water. A neighbouring sewer serving many hundreds of houses had become blocked within a few yards of the well, the sewer had consequently become surcharged and, leaking badly, had discharged much of its contents into the chalk. It could only be surmised that a septum in the chalk which had hitherto protected the well had suddenly failed and that the breach had increased in size as the pent-up liquid flowed through it while the well was being pumped to waste subsequent to the diversion of the water from supply. As it was, no impure water had been pumped into supply because the "extravagant" chlorine barrier had been capable of neutralizing the pollution until such time as it was detected by routine examination. Had the supervision been less efficient and had the material defences in the shape of chlorine dose and period of contact been less than they were, the consequences might have been quite different.

The leakage of sewage has now been remedied and the well has been restored to use. The replacement of the old steam engines by electrical power has enabled an additional precaution to be installed. This takes the form of an instrument which continuously records the residual chlorine in the water leaving the contact tank. Should the indicator of this instrument fall below a level considered to provide an ample margin of safety it makes an electrical contact which throws out a switch and the pumps are automatically stopped.

It remains now merely to touch briefly on the present-day form of chlorination equipment. The two developments of greatest import in recent years are, first, the automatic proportioning of chlorine to the flow of water being treated—though this is no new thing in itself—and, second, the automatic recording of residual chlorine. This latter equipment bids fair to control chlorination almost unaided. It has been clearly demonstrated that the slightest departures from a chosen level of residual chlorine can be translated by the residual recorder into adjust-

ments of the chlorinator so that variations not only in the flow of water but in its quality are automatically taken into account. Thus, despite fluctuations in pumping or in water quality, the residual remains steady without any manual adjustment. Dechlorination with sulphur dioxide, either complete or partial, can be controlled in the same way. Added to all this, electrically driven pumping machinery can now be automatically stopped at the instigation of the residual recording apparatus if pollution with which it cannot cope depresses the chlorine residual below a pre-determined figure.

It is not an exaggeration to say that these recent advances have revolutionised the protection of water drawn from sources of doubtful purity and have done much to refute in certain circumstances the traditional maxim, previously well justified, that chlorination alone should not be relied upon for this purpose.

Chlorination of Mains

Prior to 1939 the disinfection of water mains by means of chlorine was not general practice. It was limited to the treatment of new mains of 12-inch diameter and over. The advent of war in 1939 increased the risk of pollution of the distribution system and it was decided that mains of all sizes newly laid or after repair should be chlorinated before being put into supply and that, whenever reasonable and practicable, tests should be carried out after treatment to establish the safety of the water before restoring a main to service.

It was considered that the only fully efficient method for treating mains would be by the continuous application of chlorine to the charging water at the point where it entered the section of the main under treatment with a dose of 10 parts per million. The dosing should be continued until it could be demonstrated by tests that a sufficient dose of chlorine had penetrated throughout the whole length of the section and all its branches.

At first this method of disinfection could be applied only to large mains (of 12-inch diameter and over), the treatment being carried out with chlorine gas by means of mobile large-scale chlorination apparatus fitted on trailers. On account of the large number of small mains that were damaged, it was not

possible to use it universally and as a matter of expediency these were treated with bleach powder made into a slurry and introduced at a convenient hydrant. An analysis of the results of the mains repaired and disinfected during the years of World War II showed a marked difference in the efficiency of the two procedures. From August, 1940, until the end of 1944, a total of 807 large diameter mains were treated and only 6 of these gave evidence of pollution after a single treatment and all gave satisfactory results after a second treatment. It should also be remembered that these mains were kept out of supply until satisfactory tests had been obtained. This satisfactory experience with regard to large mains was not reflected in the results of treatment of small mains. As an example, the month of July, 1943, may be cited when a total of 118 mains was examined and of these 20 (16.9 per cent.) gave bacteriological evidence that some degree of pollution remained in them, thus indicating that the treatment had not been completely effective.

Many factors contributed to the failures obtained with the bleach method of treatment of small mains and the matter was made the topic of extensive research on a field scale at the Board's works at Willesden. Two chief factors appeared to be responsible: (*a*) the distribution of chlorine in the mains was uneven, consisting of a short wedge of water chlorinated by means of bleaching powder, compared with the ideal conditions of a continuous stream of heavily chlorinated water applied to and flushed through all parts of the section; (*b*) the demonstration that jute yarn employed as a packing material in the joints of the mains was heavily infected with bacteria including coli-aerogenes types, and that under certain conditions of water temperature these organisms as well as pathogenic types are capable of multiplying on the material. Chlorine even in doses greatly in excess of 10 p.p.m. is incapable of penetrating into the yarn and so fails to sterilize.

The first improvement introduced for the sterilizing of small mains was the adoption of a simple form of injector apparatus in which "chloros" was the source of chlorine and which applied a continuous dose of heavily chlorinated water in a simple automatic manner.

The second improvement was in the nature of the joint packing. The ideal connection for a socket and spigot water

pipe is an all lead joint and the use of a packing material which is quite inert bacterially. Unfortunately such materials are either in short supply or costly and it was decided to adopt the procedure of sterilizing the jute yarn and applying it to the joint in as hygienic a manner as possible. The yarn is sterilized by means of an organic mercurial compound and the sterilization process is under the closest laboratory supervision and analytical control, tests being carried out on samples from every 28 lbs. of yarn so treated. Mercury treated jute yarn was first brought into use on a general scale for jointing in the autumn of 1948, and continues to give satisfactory results.

The introduction of a simple automatic chlorinator for the disinfection of small mains and the use of sterile joint packing have for all practical purposes eliminated the difficulties previously experienced in sterilizing small mains, as can be seen from the following figures:

In 1951, over 2,500 small mains were tested and samples were free from *Bact. coli* in 100 ml. volumes in 99.4 per cent.; in addition an organism particularly associated with the raw jute yarn was never recovered from mains samples. Contrast the position in 1946, when approximately the same number of mains were examined and 78 (3 per cent.) of samples were unsatisfactory from the *Bact. coli* point of view and the characteristic yarn organism was isolated on 89 occasions.

In order to restore repaired mains to service as quickly as possible the practice was inaugurated at the beginning of the war of having laboratory facilities for the collection and examination of water samples from mains at any time of the day or night. This practice was found to be of such value that it has continued during the post-war years and has become an established part of the services supplied by the laboratories.

CHAPTER XXIV

Laboratory Analysis and Control

Analytical Methods and Sampling Arrangements

THE early days of water examination relied upon exhaustive analyses of relatively few samples, but experience has shown that much of the work of former times was unnecessary. To quote a few examples: full chemical analyses were carried out daily on filtered waters; bacteriological analyses included tests for several bacterial indicators of pollution; in addition, differential and confirmatory tests were carried out so that it was five days before the final result of a sample was known.

On the other hand samples from some sources such as well supplies were collected only at monthly intervals and it will be appreciated that such control of quality is not sufficiently close to safeguard against the effects of sudden and dangerous pollution. Epidemics elsewhere that have been traced to water have often resulted from accidental causes such as a sudden breakdown in purification, or flooding, or from blocked and broken drains and sewers. The trouble has not been detected immediately and it is only by more frequent and regular sampling that such tragedies can be detected early and their more serious consequences averted. The modern trend in water analysis is therefore to examine samples more frequently but to carry out less exhaustive tests on each sample and thus to secure more immediate control over the quality of the water sources and the purification procedures.

The biological section at first relied upon weekly examinations of prefiltration waters by filterability tests, microscopical examination and photographic records. At the beginning of the war, in 1939, routine photography of deposits ceased, but much closer control of the algal content of the reservoirs is now made by frequent limnological surveys of the reservoirs themselves, meteorological observations and chemical analyses.

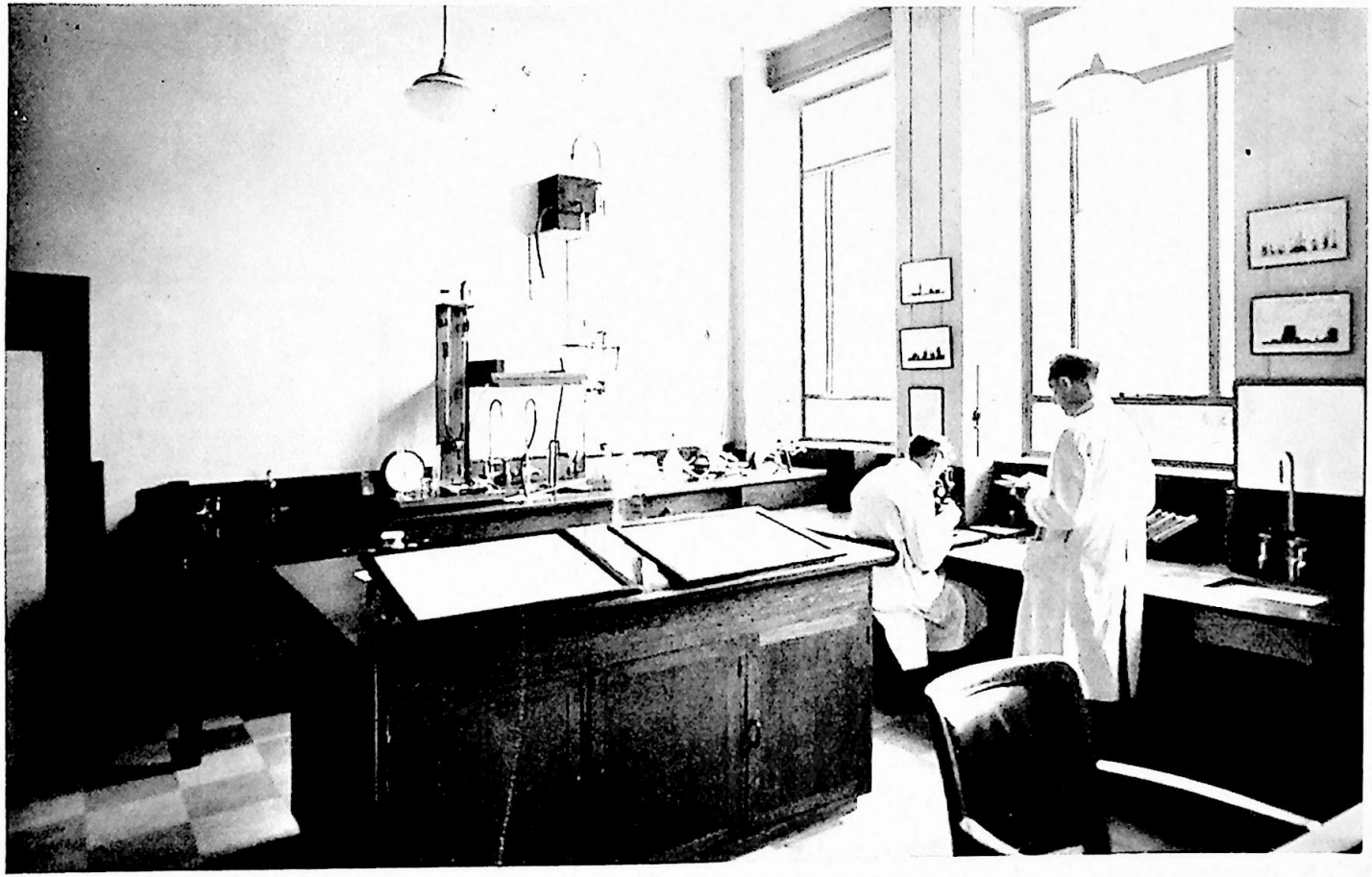
The biological surveys of reservoirs include investigations at several places and several depths with filterability tests and

microscopical examinations of samples. Chemical analysis is related to those constituents that affect the growth of algae and include estimations for dissolved oxygen, free ammonia, phosphorus and silica. The information arising from these surveys is proving of great value both in the management and the design of reservoirs.

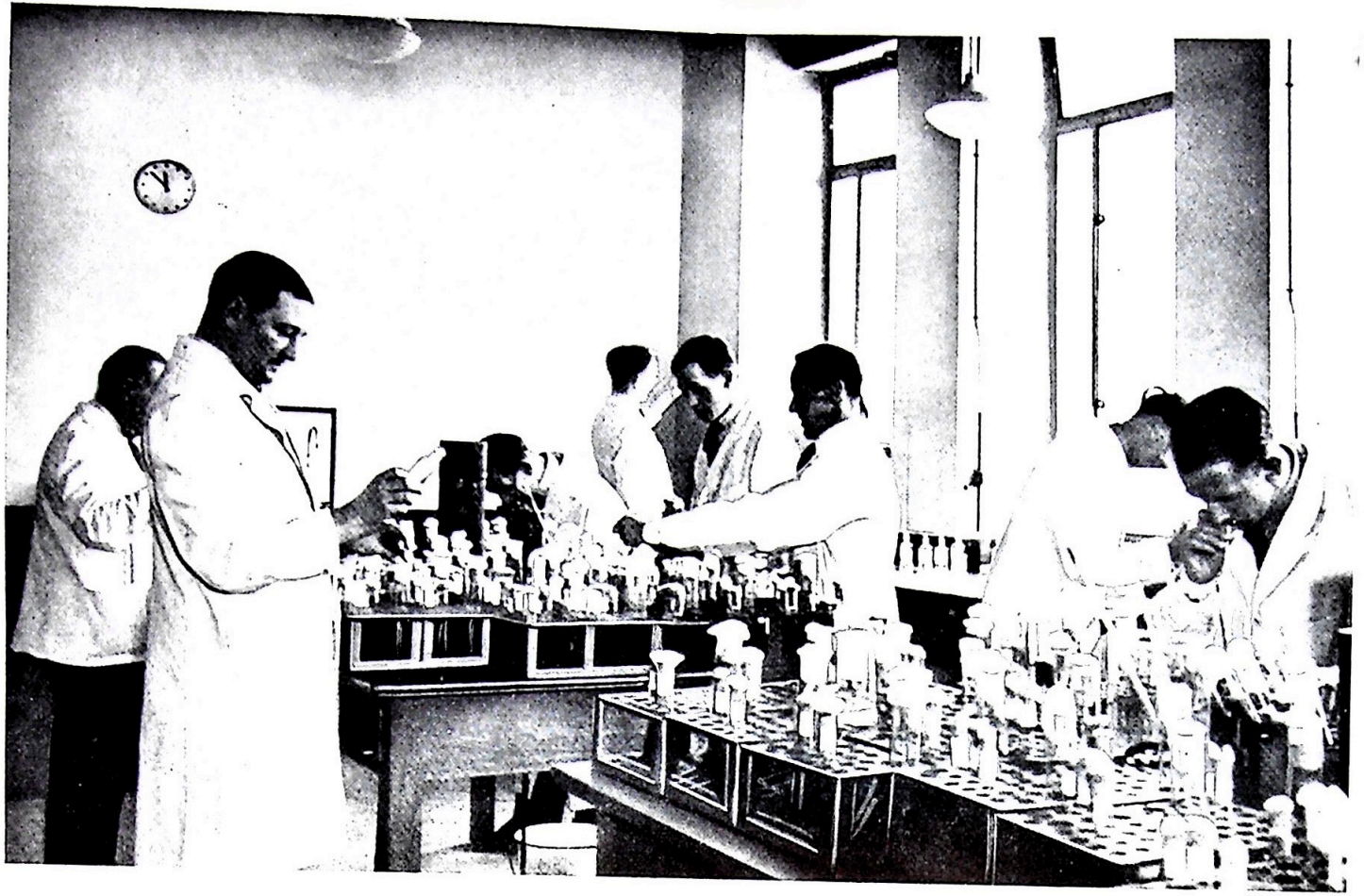
Bacteriological analysis first requires the preparation of sterile nutrient solutions and liquids to encourage the growth of any particular bacteria that may be present in a sample of water. The laboratories have always made up their own media, which amounts to several hundred thousand tubes of material annually. Prior to 1939 both beef and eggs were employed in the preparation of nutrient media, some 1,200 lbs. of meat and over 3,000 eggs being consumed each year. But even bacteria have had to adjust their diet. Needless to say, with the advent of the war and since, these two items have been superseded by meat extracts and partly digested protein preparations.

The routine bacteriological analysis of water relies on the examination for bacterial indicators of excretal pollution and an enumeration of the total number of bacteria capable of growing at 37°C. and 22°C. A complete analysis is now reserved for the investigation of new supplies and routine day-to-day control is confined to two tests, enumeration of the total number of bacteria in the sample capable of growing at blood heat (37°C.) and particularly the examination for *Bact. coli* type I, the prime indicator of faecal pollution. It is now possible as a result of the pioneer work of the present Director and subsequent modifications in the Board's laboratories, to identify *Bact. coli* type I within 48 hours of collection of a sample, and by means of the multiple tube method of inoculation of the water, adopted in 1940, a day-to-day figure of the *Bact. coli* content of waters is obtained.

Chemical analysis includes examination of the physical and chemical quality of the water and is performed as two separate procedures. A full analysis for the hygienic quality of the water is carried out on all river, stored and filtered waters once a week, and on well waters at quarterly intervals, but for works control and for ascertaining the physical quality of the water, such tests as free ammonia, residual chlorine, colour, turbidity and taste are carried out daily. (See photograph facing p. 302.)



A BIOLOGICAL LABORATORY



A BACTERIOLOGICAL LABORATORY

Experienced water tasters can identify the nature of a taste and also give a measure of its intensity by successively diluting the sample with taste-free water until the taste can no longer be detected. By such means early warning is obtained of an impending taste that may lead to complaints from consumers and it is thus possible to apply remedial measures on the works before objectionable water has passed into supply. This quite exact method of taste estimation leads to great economy in the use of materials employed for removing taste from the water.

In the case of river waters special estimations of suspended solids and biochemical oxygen demand (B.O.D.) are made for information on the quality of the water in relation to sewage pollution and extensive river surveys for general or special purposes are frequently performed.

These various examinations are based upon daily samples collected by sample collectors at all stages of water purification on the works and in the distribution system. The samples comprise specimens of raw water from the rivers and wells, stored water and primary filtered water, filtrates from all the general wells at each filtration works and from all mains pumping water into supply. Each week a full examination of the chemical and microbiological attributes of the storage reservoirs is carried out and bacteriological samples are drawn from filter wells in rotation so that the efficiency of each filter bed in service can be assessed. In the distribution system samples are collected from repaired mains, from consumers' premises either as a result of complaint or as part of the practice of random sampling. Thus a running picture is available of the water in every stage of its management from the raw material to the finished article and at the same time the quality of the water as received by the consumer is kept under constant observation.

The results of the more important analyses are recorded daily on charts displayed in a room converted for this purpose in the laboratory. These charts, commenced in 1940, form a running record of the quality of the supply from the 60 purification works of the Board. (See illustration facing p. 235.)

Examination of Employees for Detection of Carriers

In 1939 the Ministry of Health published a memorandum (No. 221) on the safeguards to be adopted in the day-to-day

administration of a water undertaking. This laid emphasis on the careful selection of workmen to be employed at waterworks and advised that they should undergo a medical examination so as to rule out so far as is reasonable and practicable any likelihood of the employment of a carrier of water-borne intestinal disease.

Since 1939, the laboratories have carried out blood tests and bacteriological tests on all employees of the Board who are likely to come into contact with the water supply. Over 2,500 men have been subjected to the blood test which is considered as no more than a "sorting" test. Should a positive result be obtained, bacteriological tests are carried out as a confirmatory procedure. If the medical history is satisfactory and all bacteriological tests are negative then the man is provided with a certificate to that effect.

A second precaution applies to employees who have been away suffering from any intestinal upset associated with looseness of the bowels. These men are kept away from their normal duties if these are likely to bring them into contact with the water until clinical and bacteriological tests have established that they are free from infection.

Since the commencement of this work on the medical examination of employees not a single carrier of typhoid or paratyphoid fever has been detected, but occasionally a carrier of dysentery or gastro-enteritis is discovered when precautions are taken to prevent him coming into contact with water until his carrier state has disappeared.

Research and special investigations

The work of the department is by no means limited to the examination of routine samples. Research is constantly being carried out in a search for improved methods of analysis and, in collaboration with the Chief Engineer's department, into improved methods of water purification. Special investigations are also carried out on materials proposed to be used in contact with water to ensure that they will not have an adverse effect on its quality.

In the constant endeavour to reduce waste of water, samples of adventitious water are sent in by the Engineer's department for tests to ascertain the probable origin of the water, that is, whether it is mains water, sewage, river or ground water. About

500 samples are examined annually with almost one hundred per cent. correct diagnosis as to whether they represent water from a main. This service is a great aid in the detection and elimination of waste.

The laboratories are frequently approached by manufacturers, industrial concerns and public utility undertakings for advice on water purification, water analysis and problems affecting their particular processes. Every effort is made to help in these investigations because they provide an ever-widening interest for the staff and are of mutual help in the knowledge imparted and acquired.

Complaints

Complaints from consumers regarding the quality of the supply are given immediate individual attention at the highest level because this is one of the most important ways in which the water undertaking comes into contact with those it supplies. A complaint may be the first indication of some defect which might not otherwise be detected in a system which comprises some 8,500 miles of distributing main. The view is taken that consumers do not put themselves to the trouble of complaining unless they have some real cause for doing so or some anxiety regarding the water. A full investigation is performed in each case with the least possible delay. Frivolous complaints are rare and a high proportion of all the complaints now received are due to defective cisterns or arise from conditions inside the building for which the Board have no responsibility. Nevertheless, assistance is given to the complainant to trace and alleviate the trouble and the value which is placed upon this service is evident by the number of appreciative letters received.

CHAPTER XXV

Legal and Parliamentary

THE Board is in law a statutory corporation and as such possesses only those powers which have been conferred on it by statute except that, in addition to the powers derived from Acts and Orders, the Board may also exercise such powers as are reasonably incidental to those expressly conferred.

Enactments under which the Board operates

By the Act of 1902, the Board was empowered to acquire by purchase, to manage and carry on the undertakings of the eight metropolitan water companies. By the same Act the Board was invested with all the rights and powers of each of the former companies and was also made subject to all the duties, obligations and liabilities of each of those companies. The Board therefore has the powers and duties contained in all Acts (whether local or general), charters, orders and other provisions relating to each of the companies whose undertakings were acquired by the Board, except in so far as their provisions have expressly or by implication been repealed by the Act of 1902 or by subsequent legislation. On the face of it, therefore, it might appear that the Board's undertaking would be subject to widely differing codes of procedure in respect of the different parts of its area. However, a perusal of the Acts relating to the former companies reveals a very considerable measure of similarity in powers and duties relating to water supply.

This similarity resulted partly from the fact that the various companies had largely adopted the provisions of the Waterworks Clauses Acts of 1847 and 1863, which contained the general waterworks code of the day. Further uniformity resulted from the passing of the Metropolis Water Acts of 1852, 1871, 1897 and 1899. These were public general enactments and by virtue of the provisions of the Act of 1897, the provisions

of the two earlier Acts were extended to cover the whole area of supply of each of the companies.

Such was the position at the appointed day. Since then the Board has from time to time found it necessary to seek further statutory powers, both general and specific. Some of the general powers obtained replace similar powers under which the companies operated and this has resulted in a greater measure of uniformity and it may now be said that the only major matter in respect of which different parts of the Board's area are treated differently is in relation to the height above which the Board is not bound to afford a supply. Limitations in this respect are still contained in the Acts of the former companies.

Since 1902 the Board has promoted fifteen private Bills which became Acts. It has also promoted various Statutory Orders. These statutory provisions have covered practically the whole field of waterworks practice.

Reference should also be made here to the Water Acts of 1945 and 1948. The Board, as a statutory water undertaker, has all the powers and duties conferred or imposed on such undertakers by these Acts except that the Board has as yet made no application to the Minister of Housing and Local Government to apply to it, nor has the Minister seen fit to apply, the third schedule to the Water Act, 1945. This schedule contains provisions which were intended to replace in a more modern form those contained in the Waterworks Clauses Acts, 1847 and 1863, and the new provisions have no operation until such time as they are applied by Order under the Water Act. As they have not yet been so applied, the Board still continues to operate under such of the provisions of the Waterworks Clauses Acts of 1847 and 1863, as have been incorporated either in the Acts of the late companies or in the private Acts which the Board itself has promoted and which have not been repealed or replaced.

However, the inadequacy of the old code contained in the Acts of 1847 and 1863 had to a large extent already been met by the Board, before the passing of the Water Act of 1945, by provisions which are contained in the special Acts promoted by the Board and which are designed to suit the special circumstances of the undertaking. Indeed, there are provisions con-

tained in the new code provided by the Water Act which are modelled upon, and follow closely provisions contained in the Board's special Acts. One instance of this is the provisions relating to the laying and maintenance of communication and supply pipes which largely follow the system initiated by the Board in its Act of 1932.

Not only did the Water Acts of 1945 and 1948 alter the general law relating to water supply, but they afforded what was designed to be a speedier and less expensive method of obtaining powers in respect of the construction of works, acquisition of water rights, compulsory purchase of land, borrowing, etc. The procedure is by way of Order made by the Minister of Housing and Local Government under various sections of the Acts, and at the present time this procedure is the general method by which water undertakers obtain powers of the kind just mentioned. This procedure therefore largely replaces application direct to Parliament by way of private Bill. It may well be, however, that undertakers applying for an Order are ultimately brought into Parliament as a result of sustained objection by those who allege that their rights are adversely affected by any Order made and who, by virtue of what is known as " special parliamentary procedure," are entitled to carry their objection beyond the Minister's decision to Parliament itself. The Board itself has taken advantage of the procedure provided by the Water Acts and has obtained several Orders under those Acts. As yet three such Orders promoted by the Board have been the subject of a local inquiry but none has been the subject of a contest before a Parliamentary Committee.

So far as Compulsory Purchase Orders are concerned, the Board is a " local authority " within the meaning of the Acquisition of Land (Authorisation Procedure) Act, 1946, and as a result its powers of compulsory purchase of land are not hedged about by as many restrictions as the corresponding powers of statutory water undertakers who do not come within the 1946 Act.

It is not only in connection with the Act of 1946, referred to above, that the Board is deemed to be a " local authority." By virtue of the duty which is imposed upon the Board to levy a precept where there is an estimated deficiency exceeding

a certain sum in the Water Fund, the Board is a "local authority" within the meaning of the Local Loans Act of 1875. This definition has now been applied in several other enactments. For example, the Board has the same privileges as a local authority in respect of borrowing money from the Public Works Loan Board under the provisions of the Local Authorities Loans Act of 1945. It may also be mentioned that like local authorities the Board is subject to the provisions of the Local Government Act of 1933 in respect of audit of its accounts by the District Auditor of the Ministry of Housing and Local Government. The Board is also for some purposes a local authority within the meaning of the Local Government Superannuation Acts. Further the Board has had applied to it the mainlaying provisions of local authorities contained in the Public Health Act, 1936.

Legal and Parliamentary work of the Board

As already mentioned in the chapter on Early Days, the Board, shortly after the appointed day, established a department to deal with its legal work. The following brief survey gives an outline of the main features of the work of the department over the past fifty years.

(i) *Legal work*

Conveyancing. The conveyancing work arises principally in connection with the acquisition of lands for reservoirs, pipelines, pumping and filtration stations and other engineering projects, and the acquisition of lands and buildings for use as offices and depots and for the accommodation of officers and employees whose duties render it necessary for them to reside in particular areas.

The statistics contained in the chapters dealing with the construction of works and the management of lands and properties indicate the large number of land transactions with which the Board has been concerned since the appointed day.

For the purposes of reservoirs alone, over the past fifty years vast areas of land in varying stages of development have been acquired, particularly in the Thames valley.

In addition, easements, wayleaves, licences and tenancies are taken by, or granted by, the Board in connection with the many and varied routine matters which arise in the day-to-day administration of the undertaking.

The Board has powers to acquire land both by way of private treaty and also by way of compulsory purchase. The greater part of the land acquired by compulsory purchase has been acquired under specific powers in this respect contained in the Board's private Acts, although since 1945 the Board has on a number of occasions taken advantage of the powers given to water undertakers by the Water Act, 1945, to acquire lands by way of an Order made under that Act.

In the majority of cases of compulsory purchase the Surveyor is able to reach agreement with landowners as to the amount of the compensation to be paid. In a number of cases, however, it has not been possible to reach agreement and it has therefore been necessary to refer to Arbitration the question of the determination of the amount of this compensation. During recent years until 1949 the reference was to an Official Arbitrator. Since 1950, following the passing of the Lands Tribunal Act, 1949, the reference is to the Lands Tribunal set up under the provisions of that Act.

By the Metropolis Water Act, 1902, power was given to acquire, hire and erect buildings and offices and for that purpose to purchase or to take on lease lands. By later private Acts of the Board these powers were extended to cover other purposes subject in some cases to a limitation of the area of land authorised to be acquired.

By the Water Act, 1945, the Board now has power to acquire land by agreement for any of the purposes of its undertaking subject to the approval of the Minister of Housing and Local Government.

A reported case of interest in regard to conveyancing matters is that of the Metropolitan Water Board v. Berton which was heard in the Chancery Division in 1921. This case decided that the Board is a "public authority" for the purposes of the Acquisition of Land (Assessment of Compensation) Act, 1919.

The construction by the Board since the appointed day of many major civil engineering works in the extension of its undertaking has involved the preparation of Conditions of

Contract upon which the contracts for these works have been let. In the passage of time these Conditions of Contract have been developed by successive Solicitors to the Board to cover the special circumstances which arise in relation to the undertaking and to meet the fluctuating conditions in industry.

In connection with contracts a reference in this place to the case of Metropolitan Water Board v. Dick, Kerr & Co. Ltd., may be of interest. This is a House of Lords decision and is a leading case on the question of discharge of contract. Dick, Kerr & Co. Ltd., had contracted with the Board in 1914, to build a large storage reservoir at Littleton, the work to be completed in six years. In 1916, on account of the war, the Government, acting under statutory powers, prohibited the continuation of the work. It was held by the House of Lords that this interruption was of such a character and duration as to make the contract when resumed a different contract from the contract when broken off and that it had ceased to be operative.

Litigation. It is almost inevitable that a large water undertaking with a vast amount of apparatus laid in highways is subjected from time to time to claims for compensation by persons who allege that they have suffered injury through the presence or condition of the Board's apparatus. It was decided as long ago as 1894, in the case of Green v. Chelsea Waterworks Company, that a water undertaker who has statutory powers to lay mains and apparatus in highways is not liable for damage to persons who suffer injury by reason of the presence in the highway of such apparatus unless it can be proved that the undertaker has been negligent. This usually means that in order to succeed the plaintiff has to prove that the Board either knew or, if it had exercised due diligence would have known, that its apparatus was in a defective condition. Many claims are received during the course of a year by the Board from persons suffering damage. The damage is usually caused as a result of fracture of mains and it is necessary for each of these cases to be carefully investigated to ascertain the precise facts so as to determine the Board's liability in the matter. The principle of the decision in Green v. Chelsea Waterworks Company has been recently affirmed in the House of Lords in the case of Longhurst v. Metropolitan Water

Board (1948), and this is now one of the leading authorities on the matter.

Another branch of the law in which the Board and their predecessors have been involved in extensive litigation is in connection with the assessment of the Board's property for rating purposes. The most recent case, which dealt with the rating of the Board's Hertford Intake on the River Lee, came before the Lands Tribunal in 1952. The method of assessment is dealt with in the chapter on lands and properties. The most important case in which the Board has been involved is that of Kingston Union v. Metropolitan Water Board (1926) in which the Court of Appeal decided, *inter alia*, that although the Board is precluded by statute from making a profit, the correct method of valuing the Board's undertaking is on what is known as the profits basis.

The most frequent source of litigation is in connection with the recovery of arrears of water rates and charges and the expenses incurred by the Board in carrying out accommodation works, and there is a section in the Solicitor's department whose function it is to recover these charges as well as to advise on the numerous complex legal points that arise in determining the proper basis of the assessment or charge or the incidence of liability. Probably no other water undertaker has a section in its legal department devoted to this purpose, but in view of the large number of consumers supplied by the Board (over six million) it is only to be expected that a considerable number of debts will from time to time be outstanding. The number of these outstanding debts however is small by comparison with the total number of accounts. The real value of the work of this section lies in the fact that the public know that every effort is being made to collect every sum properly payable by way of water rate or charges, and that default in paying such water rate or charges will result in the institution of legal proceedings. In addition the staff is always available to explain to members of the public the many difficult and complicated points which frequently arise in connection with water charges.

Many of the legal actions in which the Board has been involved over the last fifty years have arisen out of the consumer's liability in respect of water rates and charges, and some of these cases, which started as minor matters in the

County Court or Police Court, have been carried to the House of Lords for decision in view of the importance to the Board of the principle involved in the particular cases. In this connection one might instance the case of Metropolitan Water Board v. Avery (1914), which finally came before the House of Lords but which originally started as a claim in the County Court for 5s. arrears in respect of a non-domestic supply to a public house.

Lastly, perhaps mention should be made of the Police Court work which sometimes arises out of waste, misuse etc. of water supplied by the Board. Happily it has been necessary over the years of the Board's existence to take comparatively few proceedings. The only occasions when prosecutions have been at all frequent have been during the years of exceptional drought when the Board has found it necessary to impose restrictions on the use of water.

(ii) *Parliamentary work*

The Solicitor to the Board is also Parliamentary Officer and as such is responsible for the many and varied aspects of the Board's parliamentary work. This is increasing year by year, and indeed, the volume of this work, it is safe to say, has been greater since the end of the War than at any other time in the Board's history. It comprises—

(i) the promotion of any Bills or Orders necessary to arm the Board with such further statutory powers as it requires in respect of its undertaking, and

(ii) a careful watch upon all legislation, both public and private, and upon all Orders promoted by other persons or bodies which may contain provisions affecting the interests of the Board, and opposition to such Bills or Orders, or proposals for amendment of them, where necessary.

The legislative tendency at the present day is to invest a Minister with general powers to make Orders for specific purposes within the scope of Acts of Parliament and to provide machinery for the hearing, usually by way of public local inquiry, of any objections or representations which interested parties may have to make upon the proposals contained in the Order. This applies not only to the Water Acts. Almost

every new Act dealing with many other aspects of modern life such as town planning, new towns, transport, etc., contains such provisions. There are few Orders promoted by public or local authorities in the Board's area which do not affect the Board's interests in some way or other, in addition to many Orders promoted by private persons or companies. All these have to be carefully watched and, where necessary, appearances and representations made at the Inquiries held in pursuance of them. To illustrate the volume of this work it may be mentioned that since the end of the War the Parliamentary Officer or his representative has appeared on behalf of the Board at more than ninety public inquiries or local hearings. In addition, there have been many more cases where the Board has been able after negotiation to agree amendments with the other parties concerned without the necessity for formal opposition.

The most lengthy and complicated inquiry with which the Board has been concerned was that into the Board's proposals for a Greater London Water Area, referred to in detail at page 309, held before the Departmental Committee appointed by the Minister of Health.

Promotion of Bills and Orders, etc. A perusal of the chapters on engineering, finance, and lands and properties will show just how extensive have been the needs of the Board for further statutory powers over the past fifty years.

Many of the Board's Bills have been heavily contested before Parliamentary Committees. Examples of these opposed Bills are the Charges Bills of 1907 and 1921 and also the New Works Bills of 1911, 1935 and 1946. These New Works Bills have ranked among the largest new works promotions ever to come before Parliamentary Committees. This is particularly true of the Board's Bill of 1946, which involved one of the most extensive programmes of works in recent years. The proceedings before the Parliamentary Committees on some of the Board's Bills have extended over several days. The Board's Bill of 1946 was in fact challenged in principle before the Committees of both Houses. In the first House alone, 33 petitions were deposited against it.

So far as application for new statutory powers is concerned, a new era opened with the passing into law of the Water

Act of 1945. As has already been mentioned, it is now the general rule for water undertakers to obtain any powers which they require by way of an Order or Orders under this Act and the Water Act of 1948 instead of proceeding by way of application to Parliament through private Bill procedure. There still appear to be some matters which cannot be dealt with in this way, but the number of Water Bills now promoted is small. Water Act Orders can be applied for at any time during the year and the date and time of application is not regulated by the Parliamentary session as is the case with private Bills. If an application for a Water Act Order is opposed, the Minister orders a local inquiry or hearing before one of his Inspectors. Experience has shown that the procedure of these inquiries, although the issues and evidence involved may be lengthy and intricate, is much less formal than that before a Parliamentary Committee. So far as the Board is concerned the advocacy before the Inspector is normally undertaken by the Parliamentary Officer instead of by Counsel as is the practice before a Parliamentary Committee. The Orders which have already been promoted by the Board have dealt with the term of office and appointment of Members of the Board, the construction of a service reservoir, abstraction of water from the River Thames, the sinking of wells, etc.

Opposition to Bills, Orders, etc. In addition to promoting its own Bills, Orders, etc., the Board also keeps a watchful eye on the legislation promoted by other authorities which will or may affect the interests of the Board. The greater part of this private legislation is promoted by County Councils, local authorities, statutory undertakers, catchment or river boards, the British Transport Commission, etc.

Over the past fifty years the Board has presented petitions against a very large number of Bills. In some cases the Board has sought to reject the principle of the Bill altogether, but in the majority of cases it has opposed the Bill with a view to obtaining satisfactory protection for its interests in relation to the powers being sought. Scattered over the private Acts of these authorities there will be found valuable protective clauses in favour of the Board, and in several cases the protective provisions agreed by or obtained from the promoters

have become standard protective provisions in relation to the particular matters concerned and have been incorporated in private Bills all over the country.

There has been a tendency over the last few years for the number of private Bills promoted to decline. In their place there are Orders and statutory schemes promoted under various general Acts, and powers conferred by these Orders are often as far reaching in their effect as the provisions formerly contained in private Bills. In consequence, the necessity for vigilance in the protection of the Board's interests in respect of Orders is now as great as, or even greater than, in the case of private Bills. As has already been mentioned it is necessary for appearances to be made on behalf of the Board on many occasions in the course of a year at inquiries and hearings.

Before the last War the Board's undertaking was generally exempted from planning control. In the Town and Country Planning Act of 1947, however, there are many provisions which affect statutory undertakers. Further, development plans which indicate what is considered to be the proper future use of land in the various counties have been deposited and it has proved necessary for these plans to be carefully scrutinized, with a view to the protection of the Board's interests and also with a view to ensuring that sufficient provision is made in the plan for future development of the undertaking. It is often necessary for the Board to be represented at inquiries into development plans and other planning matters.

Public Bills. In recent years it has become increasingly necessary for the Board to examine public Bills.

A different procedure obtains in respect of Bills promoted by the Government from that which obtains in the case of private Bills. If the Board's interests are affected and it is felt that some amendment should be made in the Bill, the recent practice is for conferences to take place with officers of the Government Department in charge of the Bill prior to its introduction or during the early stages of its progress through Parliament. Such consultation may result in amendments being put down to the Bill.

Amongst the Bills for public general Acts in respect of which the Board has sought and obtained substantial amendments are

those for the Water Acts of 1945 and 1948 and the Public Utilities Street Works Act, 1950. On the Water Bill of 1945 more than forty amendments were put down on behalf of the Board and many of these proposed amendments were accepted and incorporated in the Bill.

CHAPTER XXVI

Lands and Properties

In 1904 the Board not only took over the administration of the eight water undertakings, but also an estate of some magnitude.

In addition to the actual sites of the works and reservoirs there was a considerable area of surplus land, part of which had been acquired for future extensions of the various undertakings and the remainder held for protective purposes. There were also numerous offices and houses, various mills and wharves and even three public houses, one of which, the Ferry Boat Inn, Tottenham, is still in the Board's ownership. The whole of this property, which extended into the counties of London, Buckinghamshire, Essex, Hertfordshire, Kent, Middlesex and Surrey, had hitherto formed eight separate estates which thenceforth had to be administered as one.

The rent roll for the year 1904–05 was £8,859, and it is recorded that during that year, twenty-seven new leases, tenancies, or licences, were granted by the Board.

The residential property taken over consisted mainly of cottages within the curtilage of the works and occupied generally by employees engaged thereat.

During the past 50 years, the Board's housing policy has been considerably enlarged, and at the present time there are some five hundred and thirty houses in their possession, most of which are occupied by officers and employees.

Many of the houses which were old when taken over by the Board, have since been replaced by new ones of modern design. This process is still continuing.

Since its formation the Board has obtained compulsory powers to acquire lands for works purposes under seven Acts of Parliament. Land has been so acquired for the following major works:

Queen Mary reservoir, Littleton; King George VI reservoir, Staines; Walton, Datchet, and Wraysbury reservoirs and Ashford Common filtration works. The approximate

By courtesy of Eric Hosking, F.R.P.S.

BIRD LIFE ON THE BOARD'S RESERVOIRS
A Heron and her chicks at Walthamstow

By courtesy of Eric Hosking, F.R.P.S.

BIRD LIFE ON THE BOARD'S RESERVOIRS
A Kingfisher at Walthamstow

areas involved and the cost of purchasing these sites are as follows:

Works.	Area.	Cost of land.
	acres	£
Queen Mary reservoir, Littleton ...	725	122,946
King George VI reservoir, Staines	350	93,292
Walton reservoir	410	172,691
Datchet reservoir	868	280,000
Wraysbury reservoir	850	257,000
Ashford Common works	131	56,115

The Various Powers Act of 1907 also gave the Board general powers to acquire lands, etc., by agreement for the protection of sources from pollution and for other purposes.

Generally speaking, the land required by the Board has been agricultural, and the negotiations for its purchase have included the settlement of numerous tenant right claims. In several cases the land was being worked for sand and gravel which involved some delicate and protracted negotiations with owners.

In the early days of the Board, compulsory acquisition of property was carried out under the comparatively simple provisions of the Lands Clauses Consolidation Act, 1845, but in later years the assessment of compensation has become more complex by reason of the provisions of the Acquisition of Land (Assessment and Compensation) Act, 1919, and the Town and Country Planning Acts.

From time to time certain works of the Board have become redundant and the sites or part thereof have been disposed of. Among these sales were Wandsworth pumping station, £12,000; part of Battersea works, now the site of the Battersea power station, and a large railway goods depot, £520,635; Sunbury pumping station (Riverside), £4,500; Fox reservoir, Ealing, £11,000; Campden Hill reservoir (one), £20,000; No. 42, Southwark Bridge Road, £25,000; 23 acres of land adjoining the pipe-track, Southbury Road, Enfield, £39,850; Ponders End mill, £6,000.

Practically all the Board's land, not actually in use for works purposes, is utilized in other ways. Over 2,750 acres, chiefly the sites of the three large storage reservoirs yet to be constructed, are let as agricultural land, and many acres are let to the Board's employees and others for allotment and garden purposes, so that the Board contribute in some measure towards food production in the Home Counties. Some of the storage reservoirs, together with certain lengths of the New River and other waters are let to angling societies for fishing. Facilities are also afforded to the public for fishing in several of the reservoirs.

The incidents of tenure which arise when dealing with the management of an estate of such varying character are diverse.

By the year 1951–52, the rent roll had increased to £33,247, and during that year one hundred and eighty-three new leases, tenancies, or licences, were granted by the Board.

Although the rents received by the Board do not appear to have increased proportionately to the number of tenancies granted, it should be borne in mind that the majority of the Board's dwelling houses are let on service tenancies at special rents which have little relation to true rental values.

In addition to the housing policy of the Board in respect of certain officers and employees, a contribution is made towards the cost of an employee's rent by means of a housing allowance in those cases where he is otherwise suitably housed on his area. At the present time there are nearly 400 of these allowances, amounting to over £12,000 per annum.

The undertaking is valued for assessment purposes on what is known as the "profits basis," although it might be better to refer to it as the "revenue basis" or "accountancy method."

The application of this method to public utility undertakings is not statutory; it has developed as the result of the consideration from time to time by the courts of the problems which necessarily arise from the endeavour to ascertain the rental value of property which, in fact, is never let, and consequently no assistance is to be obtained from the examination of the rents of comparable hereditaments.

The legislature has refrained from giving any assistance in the matter, with the result that the rights and obligations of occupiers and rating authorities over this important field of

rating are determined by rules of law which are entirely based on judicial decisions, adopting or modifying the suggestions of rating surveyors.

A number of these judicial decisions have been given on cases fought, for the most part successfully, by the Board or its predecessors.

The precise date at which the "revenue basis" was first devised is difficult to ascertain, but it was approved by the court in a case fought by the West Middlesex Waterworks Company as far back as 1859.

Although the use of this method of assessment was not at issue in the case referred to, it became one of the points for decision in the now famous case of Kingston Union and Metropolitan Water Board, 1926, when the assessing authorities claimed to make the assessments of the Board's undertaking on the contractor's basis, i.e., by applying customary percentages to the value of the land and the structural value of the Board's works in each parish. This was strongly contested on behalf of the Board and the House of Lords decided the matter in the Board's favour.

This resulted in a very considerable saving to the Board in rates.

Until the early part of the last war it had been customary for the assessment of the undertaking to be reviewed quinquennially, but since 1942, and pending the postponed new Valuation Lists authorised by the Local Government Act, 1948, it has become the practice of the rating authorities and their successors, H.M. Inland Revenue, to re-value the undertaking annually. An annual valuation is, of course, made on behalf of the Board by the Surveyor, and this procedure enables proposals to be made by either side for an increase or reduction in assessment as the case may be.

For the year 1904–5, the gross receipts were £1,928,679 and the rates and taxes paid were £273,369, i.e., 14.2 per cent.

The total rateable value of the undertaking for the following year was £1,160,781, and the rates paid thereon were £382,000 or 13.7 per cent. of the Board's total income of £2,788,321.

Although more than four decades have passed, almost a quarter of which were under war-time conditions, it is surprising to note that for the year 1951–52, when the gross

receipts for the valuation year had risen to a total of £8,869,557, the rateable value of the undertaking was of the order of £1,290,000, upon which some £1,128,200 was payable as rates, i.e., 12.8 per cent. of the total income. Thus it will be seen that although the rateable value has varied little, the rates paid have increased enormously.

The total capital structural value of the undertaking is now estimated at nearly £123,000,000, of which about £42,000,000 is in respect of mains and £28,100,000 for service pipes.

Had the Board not been successful in the Kingston case, the rateable value of the undertaking might have been very considerably higher than it is at present.

Broken Wharf and Hampstead Waterworks

During the past fifty years the Board have disposed of their interest in two historic properties connected with London's water supply.

The first of these was No. 7, Broken Wharf, Upper Thames Street, E.C., which was held from the Corporation of the City of London for the residue of a term of 489 years from 1604, at a rental of 10s. per annum. It was at Broken Wharf in 1594, that Bevis Bulmer, a mining engineer with wide interests in England and Scotland, erected a "Forcier," as Stow describes it, "for conveying Thames water into men's houses in the west part of the City." The undertaking subsequently came into the hands of one Thomas Parradyne who was granted the above-mentioned lease from the City. At the beginning of the eighteenth century Broken Wharf was acquired by Richard Soame who had purchased London Bridge Water Works from the Morris family, and it was conveyed as part of those waterworks to the New River Company in 1822. In 1925, the Board decided to sell their interest in the property by public auction, but it appeared that under the lease they were under an obligation to offer the property in the first place to the City Corporation and moreover they were forbidden to sell to any person not being a free citizen of the City of London. After negotiations the City agreed to accept a surrender of the 1604 lease and to grant a fresh lease of the property for a term of 167 years from 21st August, 1924, at a rental of £1 per annum. The difficulties as

to assigning the property having been removed it was sold by public auction on 12th May, 1927, and realised £3,000.

The other property was the Hampstead and Highgate Ponds, the reservoirs of the former Hampstead Water Company. This company was formed in 1692, by William Paterson, founder of the Bank of England, and others to exploit certain statutory powers obtained by the City Corporation in 1543, for making use of "dyvers great and plentyfull springes at Hampstede Hethe" and elsewhere within a radius of five miles from the City. These powers were assigned to them together with certain ponds, by the City Corporation for a term of thirty-one years renewable after twenty-one years. According to their own petitions, the undertakers and their successors never made anything out of the business although further ponds were constructed in the eighteenth century. The company's works were eventually taken over by the New River Company in 1856, for a perpetual rent charge of £3,500 per annum, which the Board are still paying. Since the time the New River Company took over, the pond water had not been used for domestic purposes. The ponds were held by the Board on lease from the Corporation of the City of London, at a rental of £80 per annum, which lease was renewed in 1929, for a further period of seven years expiring at Midsummer, 1936, when it was not renewed.

CHAPTER XXVII

The Second World War

As, after Munich, the clouds of war began to gather, the Board devoted their attention with great earnestness to the question of maintaining the supply under the worst foreseeable conditions.

Conferences were held, available methods and apparatus were reviewed, and experiments were performed, until an outline of what the future might bring and what steps might be taken to meet it began to take shape. It seemed justifiable to believe that the first manifestation of a state of war might be an aerial onslaught upon the Capital City and that the works of the Metropolitan Water Board would be selected as a special target for destruction. Upon this belief the plans for ensuring the continuance and purity of the supply were based. The lull between the declaration of war in 1939 and the fierce onslaughts of late 1940 gave further opportunity, which was well used, to strengthen the organisation, protect the works, purchase stores and materials, and generally to bring the whole system into gear with the war economy. The prudence of the measures adopted was not to wait long for its vindication.

The Board's two-fold task of ensuring (a) the maintenance of the supply and (b) its purity, had to be viewed in the light of the disastrous consequences which might have ensued from a serious disturbance in either direction. Domestic consumers, hospitals, factories, the fire-fighting services—the needs of all had to be met. A major breakdown, whether at the source of supply, at the pumping stations, in the distribution system, or in the purification arrangements, could have brought dire consequences in its train. To afford complete immunity was not possible. The task resolved itself therefore into providing such physical protection as was possible and to have in reserve, immediately available, a large quantity of machinery, materials and equipment. This, in itself, was not so simple as it sounds. The works were, for the most part, at a considerable distance

from the centre of demand and connected to it by many miles of mains laid underground. Serious damage to a major pumping station could have had grave consequences unless alternative sources of supply and means of distribution could be provided.

Not less important than the maintenance of a sufficient supply was the task of safeguarding its purity. Before describing the measures which were taken to this end it would be well to picture what might have been the consequences had the water from one of the Board's major works become infected with the germs of typhoid, which is now the most to be feared of all the water-borne diseases.

Judged by past epidemics, it might be expected that infection of a filtration works of average size would result in 16,000 cases of typhoid, with 1,600 deaths, and the establishment of between 300 and 800 permanent carriers of the disease as a reservoir of infection for the creation of further outbreaks. The significance of this can best be appreciated by comparison with the Croydon epidemic of 1937, in which occurred 323 cases and 43 deaths. Many will recall the widespread feeling of alarm and the sense of insecurity which prevailed amongst those residing within the area affected by this comparatively minor outbreak.

The foregoing estimate inadequately represents the probable state of affairs, for the water delivered from any one of the Board's works does not supply an isolated area. There is widespread intercommunication between the water mains throughout the distribution system and even a comparatively small quantity of infected water might contaminate that supplied from other works. It is therefore not possible to place any limit upon the consequences of contamination of the supply from any particular works.

It is not difficult to picture what might have been the effect upon the morale of the people of so disastrous an occurrence, and of the knowledge that each such incident would increase the probability of further similar epidemics.

The events of the grim days of the aerial attacks on London are so vividly in the memory of many that it is not necessary, nor perhaps is it desirable, to recount the experience in detail. In what follows only the principal steps taken by the Board are described. It is convenient to group them according to

their function (i.e. whether engineering or purification), but it should be stressed that in practice the whole system was one and that the closest co-operation existed at all stages between those responsible for either aspect of the undertaking.

Engineering

A large amount of pumping machinery was purchased, partly by the Board and partly in conjunction with neighbouring water undertakings. Pumping connections were made at most of the main pumping stations so that the mobile plant could speedily be set to work in the event of damage to the permanent machinery. Numerous supplies of electric power were laid on to enable the mobile plant to run on purchased energy.

An elaborate system of intercommunication was established so that several alternative supplies were available in most areas. New large mains were laid and connections between existing mains made and, contrary to normal practice, hydrants were fixed on trunk mains, at the request of the National Fire Service, in order to augment supplies of water for fire fighting in certain areas. The needs of specially vulnerable and important areas were catered for as far as possible by isolating some large trunk mains in order to deliver water direct to them.

As far as was possible in the circumstances of the time, physical protection of the machinery was afforded by erecting structures of reinforced masonry or of steel. The very stringent black-out measures undertaken involved in some cases, as for example in the boiler houses, much discomfort for the men operating the plant. Air raid shelters as required for personnel were put up.

The possibility of serious and extensive damage to the mains had been visualised, and a system of distribution of water by tank waggon worked out. Plans were also made for the emergency distribution of drinking water from privately-owned wells and surface sources in the event of the Board's own sources being put out of action.

Plans were also drawn up to meet the eventualities which might arise in London following an invasion of the country.

Purification

High in the order of priority of safeguarding the purity of the supply came the necessity to ensure that there should be no interruption in laboratory examination and control of the supply, for without this there would have been no means of assessing the need for, or the success of, other measures. Among the first steps to be taken were the selection of suitable buildings in comparatively safe areas and their conversion into alternative laboratories. Before the outbreak of war these emergency laboratories were fully equipped and ready to be brought into operation without interruption of the work.

The use of prechlorination, in high dosage when necessary, was extended to all filtration works, thus ensuring that the water was in a state of considerable bacterial purity before reaching the filters. This increased the main lines of defence to four, namely, storage, prechlorination, filtration and terminal chlorination. This was undoubtedly the most important factor in preserving the purity of the water pumped from the works, for there was no occasion upon which less than two of these lines remained intact.

The residual chlorine in the water passing into supply was increased to the highest level consistent with the avoidance of serious cause for complaint. Complaints there were, but when the reason for the taste was explained to the people it was gladly accepted and, indeed, welcomed. This provided against pollution through infiltration of ground water into broken filtered water channels and also gave some protection against failure to effect complete sterilization of fractured mains as a result of either physical difficulties, which often existed, or the fallibility of human nature. The value of residual chlorine has frequently been exaggerated, but its limitations were fully appreciated and its presence was not permitted to allow of any relaxation in the more positive methods of protection.

The possibility of the introduction of chemical poisons into the water either deliberately or accidentally, as by the use of poison gas bombs, was countered by a system of guards at works and reservoirs and by arrangements for the immediate testing at the works for poisons should there be any suspicion

that the water might have become contaminated. A staff of analysts and sample collectors was also maintained at the central Laboratories day and night for the purpose of carrying out confirmatory tests, and daily examination for poisons was made on samples representing the contents of every pipe passing water into supply from the filtration works.

It will be evident that chlorination was to play a most important part in the Board's defensive measures, and it was necessary that every possible step should be taken to prevent any interruption in this vital process. Although chlorination had been in use by the Board for a considerable time, it was still regarded as somewhat subsidiary to the older purification processes. This view had now to be revised, for acts of war might at any moment have rendered it the most important or, indeed, the only barrier against the spread of water-borne diseases.

A programme involving the alteration and adaptation of a number of buildings was put into effect. Where unsuitable premises were in use, new buildings of blast- and splinter-proof construction were designed; where existing structures could be adapted and protected this was done; where necessary, chlorinating instruments were duplicated and for every chlorinating point a duplicate was provided at a distance from the existing building in case this should be destroyed.

To provide against failures of water pressure essential to the operation of chlorinating instruments, alternative supplies were provided from two or more sources; in many cases special pumps were installed to boost the pressure or to furnish an independent supply; a reserve of portable pumps was maintained in readiness for immediate transportation and installation wherever they might be required. It was anticipated that it might become necessary to apply chlorination, in emergency, at points where no apparatus existed, and for this purpose a large number of portable gas chlorinators and wooden huts were purchased. Special chlorine gas diffusers were designed which would enable the gas to be fed directly into the water where suitable conditions existed instead of being delivered as a solution of chlorine, should no water supply for this purpose be available. Whenever and wherever there was interruption to chlorination it was possible to re-establish it within a few minutes. This work involved the de-

tailed consideration and re-planning of over 150 chlorination points.

There could be no doubt that the most serious danger would be created by the fracture of water mains and sewers in close proximity in the streets, resulting in the admission of sewage to the water mains. Protection against the consequences of such incidents was provided by the rapid closure of valves by turncocks and by instructions to the effect that no main should be put back into supply after repair until it had been thoroughly flushed and disinfected by chlorine. Whenever possible, repaired and sterilised mains were examined bacteriologically before being restored to supply, but frequently they were so urgently required for fire-fighting that this could not be justified. Sterilisation by chlorine was, however, never omitted and large mains involving a widespread risk were invariably examined bacteriologically before being restored to use. Special mobile chlorinators were provided and the whole of London was divided into areas, to each of which some were allotted. Central control was maintained and a number of chlorinators were held in reserve, thus enabling relief to be provided in districts where the work was exceptionally heavy. Some difficulties in the rapid sterilisation of mains were encountered in the early days, due chiefly to the almost complete disorganisation of communications, but these were rapidly overcome and, as experience was gained, the whole organisation worked smoothly and without avoidable delay.

It was not only necessary to preserve the purity of the supply. When the enemy resorted to fire-raising, considerations of purity had to be moulded to those of quantity, for without water London might have been destroyed by fire. The greatest need for water frequently coincided with heavy damage to the works and consequent limitation of their output. Decisions had to be taken, often on the spur of the moment, as to the extent to which orthodox methods of purification might be discarded to increase production without imperilling the health of the people. There is no hard and fast line between a safe and an unsafe water, and such momentous decisions were not easily taken, for they had, of necessity, to be based upon personal opinion. It must be admitted that the taking of them was assisted by the gravity of the situation and it can fortunately

be said that there was no occasion when the quantity of pure water available was insufficient, or when there was any deterioration in its bacterial purity.

Distribution of water in emergency

In the light of experience gained during the air attacks on London in 1940–41, the Board gave careful consideration to the arrangements to be made for the distribution of drinking water to consumers in emergency, and certain schemes were quickly completed. These would have been brought into operation in the event of serious emergency, such as might have arisen from very heavy aerial bombardment or attempted invasion, but every effort was made to maintain piped supplies by the normal methods.

It was foreseen that extensive damage to the Board's works, mains and distribution system might have been caused by heavy air attacks, with resulting serious interruption or cessation of piped water supplies within parts of the area, and it might even have been necessary for supplies to have been restricted deliberately. Furthermore, in the event of exceptionally large quantities of water being drawn from the mains for fire fighting or as the result of serious damage to the Board's works, there was a possibility of the water supply being dangerously polluted over a wide area. Arrangements were made whereby all consumers would have been given immediate notification if that had happened. Plans were also prepared to enable limited quantities of drinking water to be distributed to the inhabitants to the extent necessary to maintain life, even if all the Board's works were put out of action.

The possibility that serious damage might be sustained by the distribution system (i.e. by the trunk and service mains) while the works were still able to function was envisaged. One thousand specially designed tanks, each holding 500 gallons, were obtained and arrangements were made with the Ministry of War Transport for lorries to be available at very short notice for carrying them. In addition, many local authorities and industrial concerns agreed to lend tankers, and in this way a large fleet of vehicles was built up which, after being sterilised, could be used to carry water to the inhabitants. Special plans were made for supplying hospitals, rest and feeding centres

and premises engaged on vital food production, such as bakeries. Fortunately it was not necessary to bring the whole scheme into operation but on a few occasions a number of tanks were used to supply small areas.

Alternative supplies from private wells and surface sources

In order to provide for the possibility of the Board's works and mains being so badly damaged that the supply from normal sources could not be maintained, arrangements were made with the owners of many private wells throughout the area for the Board to draw water from these wells for distribution, if necessary. Nearly all these wells normally supply water of considerable purity, but it was not unlikely that, if conditions in London became such that the wells had been required for use by the Board, some of them might have become polluted. Plans were therefore made to chlorinate all water from them before distribution to the public.

Owing to the location of the Board's wells, which are not spread uniformly throughout the area of supply, there are many places which are remote from any well and for which other arrangements had to be made. All available sources of water which could be used in emergency, such as rivers, streams, lakes, ponds and water-bearing gravel beds were surveyed. The purification and treatment of the water from these various sources to provide a potable and safe drinking water presented considerable difficulty. Samples of water were taken from all apparently suitable sources and experiments were performed in different methods of treatment and actual trials were carried out at a number of sources. As a result of experience gained, much special plant and apparatus, including mobile filtration and chlorinating units, pumps and tanks, were provided and, in addition, purification plants at a number of swimming baths with certain modifications were incorporated in the scheme. The scheme, which embodied and extended the tank waggon scheme referred to above, required the most detailed enquiries and extensive organisation to ensure efficient working at short notice in an emergency.

One of the many difficulties which faced the Board in the preparation of their emergency schemes was the finding of sufficient persons to help in operating them. It was ultimately

decided, with the co-operation of local authorities, to call for volunteers locally and to train them in advance for the duties they might have to undertake. Over 7,000 volunteers were trained.

Method of control during air attacks

A local control room was established at each district engineer's office which was manned continuously throughout the twenty-four hours. In addition, a messenger service was also available in the event of a breakdown of the telephone system and other special means of emergency communication were evolved in conjunction with the G.P.O. and the Police.

The central control room was located at the Board's Central Offices at New River Head, Rosebery Avenue, where the Chief Engineer, or his deputy, and the distribution engineer, or his deputy, were continuously on duty.

By means of the complex intercommunication arrangements of the distribution system, it was possible, and frequently necessary, to pump water from the Thames valley to districts in the northern or eastern parts of the area to a much greater and wider extent than normal, when the ordinary or local methods of supply failed, usually because of damage to mains.

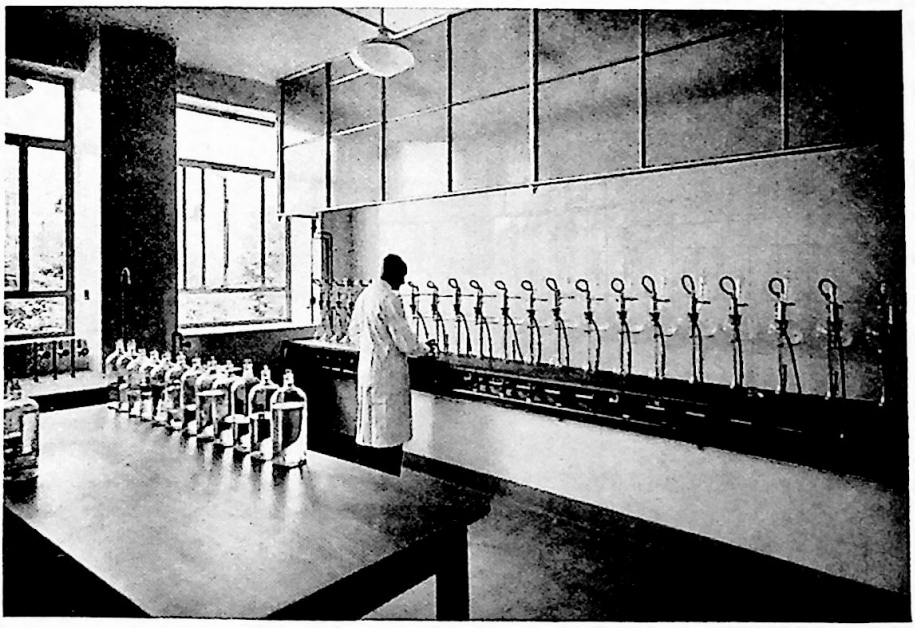
As things turned out, the greatest damage sustained was to the mains, many hundreds of which were broken in a single raid, and the problem was not so much the finding and purifying of sufficient water but of delivering it to the consumers throughout the 540 square miles for which the Board are responsible and which included the most heavily bombed part of the country.

Private telephone lines were installed between the Board's central control room and the London Regional Headquarters of the National Fire Service. The Board were notified as quickly as possible of all major fires and were kept informed how each situation was developing. In that way it was possible to some extent to anticipate the demand on the mains in any particular district for fire fighting and to arrange for increased rates of pumping and the transfer of water, often at a higher pressure, from one area to another.

Each district engineer was in touch with the appropriate officer of the National Fire Service for his district and also with

FILTER BED CLEANING, WINTER, 1939–40

Masses of ice must be removed from the frozen beds before cleaning can proceed. Deoxygenation may cause difficulty in regard to taste.



DISTILLATION ROOM, CHEMICAL SECTION

A WATER MAIN FRACTURED BY BOMBING, 1940

his "opposite number" in the gas and other undertakings. Arrangements were made for mutual help which on occasions proved of the greatest value.

Representatives of each of the services were on duty at London Civil Defence Regional Headquarters in order that incidents affecting the utility services could be studied as a whole.

Damage to Board's works and mains

Fortunately none of the Board's pumping stations received a direct hit, but bombs fell very close—the pumps in one case being completely buried in debris. Bombs fell within the curtilage of the works at Lee Bridge, Stoke Newington, Hornsey, Cricklewood, Hammersmith, Barrow Hill, Campden Hill, Deptford, Shortlands, Battersea, Kempton Park and Surbiton. There was virtually no damage to permanent plant.

The banks of the Board's storage reservoirs (including Queen Mary, Bessborough, Chelsea No. 3, Barn Elms, and others) were hit by H.E. bombs of varying sizes on no less than 30 occasions. At the outbreak of war the top water level of most of the reservoirs was lowered 5 feet as a precautionary measure and, partly because of this, none of the reservoir banks was ever breached sufficiently to allow of the escape of water, and very little inconvenience was felt as a result of these hits.

Some of the filter beds received considerable damage, during the heavy bombing, at a large number of the Board's works, including Surbiton, Walton, Barn Elms, Barnes, Kew Bridge, Hanworth Road, Hampton and Lee Bridge, and this at times caused serious limitations to the filtration area.

Several of the Board's raw water conduits were damaged at various times but no serious consequences resulted as in most cases alternative routes were available.

An incident relating to the New River is worth recording in this account.

A length of the New River known as the Enfield Loop is by-passed by one 54-inch and two 48-inch diameter mains. Part of the redundant loop was transferred to the Enfield Urban District Council in 1938, and the length within the Borough of Edmonton was sold and subsequently filled in for a length of about $\frac{1}{4}$ mile.

In October, 1940, the three mains referred to were broken by one bomb and the flow of the river was completely cut off to the extent of 46 million gallons per day. With the co-operation of the London Regional Defence, the help of the London Fire Brigade, and the immediate assistance of the Army, the original course of the river through the "Loop" was brought into use. Twelve hundred men of the A.M.P.C. excavated that part of the old course of the river which had been filled in and a considerable portion of the supply was restored within 24 hours.

If the major works of the Board escaped with very little damage, the distribution system was hard hit. No less than 6,635 mains were damaged, of which 875 were of 12 inches diameter or over. On the night of 10/11th May, 1941, the worst experienced as regards such damage, 605 mains suffered, of which 98 were of 12 inches diameter or over.

Almost every conceivable form of damage which might have prejudiced the purity of the supply was inflicted upon the undertaking. Damage to sewers in the outskirts of London necessitated the discharge of untreated sewage into the river from which raw water supplies were drawn; reservoirs were cut off from the works by the destruction of aqueducts, thus necessitating the passage of unstored raw river water to the filters, and bombs fell into the filter beds and caused short-circuiting between the unfiltered and the filtered water channels. At times it was necessary to by-pass the slow sand filters to enable the supply for fire fighting to be maintained. The damage to the distribution system frequently meant that mains became heavily charged with sewage. All the necessary protective measures were, however, in readiness.

Consultative Committee for the Director of Water Examination

In 1941, at the suggestion of the Director of Water Examination, a Committee was formed of eminent scientific men whom the Director could consult and from whom he could seek advice on matters concerning the purity of the Board's supply. The Committee, known as the Consultative Committee for the Director of Water Examination, was constituted as follows:

The Rt. Hon. Lord Horder, G.C.V.O. (Chairman).
Dr. James Ferguson, K.H.P., B.A., M.B., D.P.H., Medical Officer of Health, Surrey County Council. (Representing the Home Counties Branch of the Society of Medical Officers of Health).
Dr. Mervyn Gordon, C.M.G., C.B.E., F.R.S., M.A., M.D., B.Sc.
Dr. Thomas Orr, M.D., D.Sc., Medical Officer of Health, Borough of Ealing. (Representing the Royal Sanitary Institute).
Lt.-Col. G. S. Parkinson, D.S.O., M.R.C.S., L.R.C.P., D.P.H., The Dean, The London School of Hygiene and Tropical Medicine. (Representing the London School of Hygiene).
Dr. Maitland Radford, M.D., B.S., D.P.H., Medical Officer of Health, Metropolitan Borough of St. Pancras. (Representing the Metropolitan Branch of the Society of Medical Officers of Health).

The Committee gave willingly of their time and knowledge, studied in detail all the measures which had been taken for protecting the safety of the supply and gave valuable assistance in many matters connected therewith.

The Board, on 18th October, 1946, recorded their appreciation of the services so rendered.

War Emergency Water Committee

In December, 1940, a War Emergency Water Committee for the London Civil Defence Region was formed and consisted of representatives of all the water undertakings within the Region. This Committee, under the Chairmanship of Mr. Henry Berry, C.B.E., then Chairman of the Board, co-ordinated the work of maintaining the water supplies within the Region on a basis of mutual help in emergency.

Security measures

From the outbreak of hostilities, measures were adopted for the protection of the Board's works against sabotage. These measures were intensified as the war reached a more critical stage following the invasion of the Low Countries and included the adoption of a strict permit system to ensure that

only duly authorised persons were admitted to the works; the extensive use of barbed wire; the fitting of steel doors at the entrances of tunnels containing mains, and arrangements for patrolling the banks of reservoirs. Periodical inspections were made by the Security Officer and the assistant security officers to test the efficiency of the measures adopted. In addition to these security measures the Board's battalion of the Home Guard, referred to more fully in Chapter xxx, maintained nightly and week-end guards at all the principal stations.

CHAPTER XXVIII

Greater London Administration

THIS chapter deals with two Inquiries touching the administration of water supplies in the Greater London area during the half-century. The first, by the Royal Commission on Greater London, 1921–1923, was initiated by the London County Council, and considered the subject as part of the general question of Greater London Administration. The second, by the Departmental Committee on Greater London Water Supplies, 1946, arose from proposals submitted by the Board and examined the matter in considerable detail.

Royal Commission on Greater London, 1921-1923

A Royal Commission was appointed in 1921 to inquire and report what, if any, alterations were needed in the local government of the Administrative County of London and the surrounding districts, in order to secure greater efficiency and economy in the administration of local goverment services, and to reduce inequalities which might exist in the distribution of local burdens between parts of the whole area. The Chairman of the Commission was the Right Hon. Viscount Ullswater G.C.B., and the Commission held its first meeting on the 6th December, 1921. The London County Council proposed that a new "Central Authority" should be set up to administer, among other central services, the metropolitan water supply and that the Metropolitan Water Board should be abolished.

In December, 1921, the Board resolved to oppose this proposal of the London County Council and the Chairman of the Board, Lt.-Col. J. B. P. Karslake, and a past Chairman of the Board, Mr. E. B. Barnard, were deputed to give evidence in support of the case, as being representatives of the interests of the London County Council and the outer London Authorities within the Board's limits of supply.

The Board submitted a memorandum in March, 1922, and were subsequently informed that the Commission did not feel

it necessary to ask representatives of the Board to support the memorandum.

The majority report of the Royal Commission, dated 27th February, 1923, contained the following paragraphs :

> "The (London County) Council drew attention to the fact that the area of the Metropolitan Water Supply was very much greater in extent than the area of the administrative county of London and suggested that the administration of water supply had been entrusted to a special body because there was no existing municipal authority with jurisdiction over an area appropriate to this service.
>
> "The representatives of Local Authorities and other bodies which did not object in principle to the administration of water supply by an indirectly elected Authority offered little criticism of the Metropolitan Water Board from the point of view either of efficiency or of economy. . . . The representatives of Local Authorities and other bodies which proposed to replace the Metropolitan Water Board by a directly elected Authority based their view rather upon the desirability of bringing the administration of water supply into harmony with that of other services under a general re-organisation of local government than upon any indictment of the present practice of the Board.
>
> "In regard to this service we find that no case has been made out for transferring the powers and duties of the Metropolitan Water Board to a Central Authority such as was proposed by the London County Council. The area covered by the system of the London water supply would not coincide with the area proposed for the Central Authority, and there has been scarcely any suggestion that the work of the Metropolitan Water Board is not well carried out. There has been considerable criticism of the principle on which the Board is composed, namely, that of indirect election by the members of elected local authorities. But we consider it established that the control of the electors over their representatives on the Board is sufficient if due regard is paid to the nature of the Board's work. Water supply in and around London is a service managed on principles which are now well defined and do not raise many contentious issues.
>
> "We received from the Metropolitan Water Board at an early stage of our inquiry a full statement in writing of the facts as to their area, constitution and functions, including particulars of action taken in pursuance of the recommendations of the Departmental Committee on the Metropolis Water Act, 1902, which reported in 1920. In view of the recent date of this inquiry we considered it unnecessary to examine the Board's methods of administration afresh, or to ask the Board to amplify in oral evidence the information which they had sent to us in writing."

Departmental Committee on Greater London Water Supplies, 1946

In 1944 H.M. Government issued a White Paper entitled "A National Water Policy" outlining proposals for ensuring a planned and economical use of the water resources of the country and the efficient administration of water supply services. It considered that there was a *prima facie* case for the establishment of a Regional Advisory Water Committee for the Greater London Area.

The Board, after a close investigation into the many factors involved—hydro-geological, engineering, financial, administrative—came to the conclusion that a Joint Advisory Committe was not the best way of achieving the desired ends in this area and submitted their own proposals which they made public.

In November, 1946, the Minister of Health set up a Departmental Committee to go into the matter. The Committee was constituted as follows:—

R. Moelwyn Hughes, Esq., K.C. (Chairman)
Sir Frederick Alban, C.B.E., F.S.A.A., F.I.M.T.A.
Sir Charles des Forges, C.B.E.
F. J. Dixon, Esq., C.B.E., M.I.C.E., M.I.Mech.E., F.G.S.
Sir Roger Hetherington, C.B., O.B.E., M.A., M.I.C.E.

Its terms of reference were:

> "To examine the present system of water supply administration in the Greater London area and to consider and report on the question whether changes in that system are desirable in the public interest and, if so, what should be the constitution, powers, and duties of the new body or bodies in which control should be vested."

The Committee held 13 public sittings during the period from 10th March to 23rd June, 1947. Evidence in support of the Board's case was given by Mr. Harold Gibbons, O.B.E., J.P., Chairman of the Board; Mr. Hugh Franklin, Chairman of the Works and Stores Committee; Professor P. G. H. Boswell, D.Sc., F.R.S.; Sir Jonathan Davidson, C.M.G., M.I.C.E.; Mr. H. F. Cronin, C.B.E., M.I.C.E., Chief Engineer of the Board; Lt.-Col. E. F. W. Mackenzie, O.B.E., M.B., D.P.H., Director of Water Examination; Mr. J. R. Taylor, M.I.C.E., and Mr. Arthur Collins, F.I.M.T.A.

The Board's proposals attracted considerable opposition and a large number of memoranda, the majority of which were critical of the proposals, were deposited.

During the course of the hearings and also by written statements, a vast amount of technical and other information was placed before the Committee. In their subsequent Report practically nothing of this important material was published and as this was without doubt the fullest inquiry into the water resources of the area since the Balfour Commission of 1892, it is thought desirable to outline the matter in this Review for the benefit of those to whom the technical reports are not readily available. The statistics given are those obtaining at the time of the Inquiry.

The Board's Submission

The Board's submission may conveniently be summarised under three main headings following the Committee's terms of reference, namely:—

(1) The present system of water supply administration in the Greater London area.

(2) Whether changes in that system are desirable in the public interest, and, if so,

(3) What should be the constitution, powers and duties of the new body or bodies in which control should be vested.

1. *The Present System of Water Supply Administration in the Greater London Area.*

The public water supply in the suggested area is administered by a large number of water supply authorities comprising, in 1947, 36 Boards or local authorities and 29 private water companies. The approximate population supplied was 10,200,000 and the average daily supply about 465 million gallons.

The Board are by far the largest of the water authorities in this area, supplying, in 1947, an average daily quantity of 332 million gallons to a population of about 6,280,000 persons.

Particulars of the various classes of water authority arranged according to the population supplied are as follows:—

Authorities supplying				*No.*
Over 6,000,000 persons				1
500,000	,,	to 1,000,000		2
250,000	,,	,,	499,999	3
100,000	,,	,,	249,999	4
50,000	,,	,,	99,999	6
25,000	,,	,,	49,999	11
15,000	,,	,,	24,999	12
Less than 15,000				26
				65

2. *The Desirability of Changes in the Public Interest*

(*a*) *Irregularity of existing boundaries.* The boundaries of the areas of supply of the existing water undertakings are of an extremely irregular character and do not appear to have been settled upon any physical or administrative basis. They do not follow geological boundaries or boundaries of local authorities. Moreover, in several cases, the area of supply of one undertaking is split into two or more parts by the area of supply of another undertaking. There are a number of instances of narrow promontories supplied by one undertaker jutting into the area of supply of a neighbouring undertaker.

(*b*) *Multiplicity of undertakers.* The Board took the view that many of the existing undertakings were too small to give satisfactory and efficient service or to have sufficient resources to meet an emergency, neither could they employ the specialised staff which is desirable in connection with the provision of a public water supply. Many of them were supplying less than 50,000 persons each, or in approximate terms of quantity of water, less than 2 million gallons per day.

The Board submitted that their proposals were in accordance with the policy laid down in the White Paper and that the suggested area was of a size which was both reasonable and capable of efficient administration.

(*c*) *Hydro-geological unity of the suggested area.* The area known as the London basin forms in general a single hydro-geological unit, in which the behaviour of underground water follows well-known laws. Abstraction of water at any point within the

basin affects to a greater or lesser extent the conditions throughout a wide area. The case for a unified control of the water resources of the Greater London area rests primarily on the geological structure and distribution of formations; moreover, the area is conveniently adjusted to the topographical features of the region which have largely been determined by the geology. The geological characters of the region follow a definite pattern on which the limits of the suggested area were mainly based. This area is almost coincident with the aggregated catchments of the affluents to the Lower Thames below Marlow.

From the hydro-geological standpoint, the area is unique in Britain, for nowhere else is there a structural basin yielding such a large quantity of water from underground sources or so favoured economically by having its supplies naturally and continually delivered from an arcuate, sparsely populated, catchment zone into a central densely populated district of high demand.

Although the London basin forms one unit, the suggested area did not entirely coincide with it because in the Board's view such an area would not readily lend itself to efficient administration and is, in fact, an unattainable ideal. The area which the Board were advised should be placed under unified control does, however, approximate to the ideal and is almost equidimensional from north to south and from east to west and is centred on the district of densest population and greatest demand.

(*d*) *Community of interest of the suggested area.* There is a considerable measure of community of interest and interdependence throughout the area within 30 to 40 miles from the centre of London fostered by a highly developed system of communications. The suggested area although independently considered by the Board coincides roughly with the Greater London area proposed as a Planning Unit by Sir Patrick Abercrombie in his Greater London Plan. The movement of population and resiting of industry on a larger scale, which the development of this plan will entail, necessarily carry with them changes in the water requirements of different parts of the area and these changes will tend to accentuate considerably the present maldistribution of resources and supplies. It is axiomatic that the provision of an adequate supply of water is

the first essential of a community and the Board regarded it as imperative that development of new towns or of existing ones should not be prevented or hindered by lack of this vital necessity.

(*e*) *Adequacy of supply in the suggested area.* The consumption of water in and around London has been increasing for many years. This increase is likely to be further accelerated by the changing habits of the population and by the provision of vast numbers of new houses with modern water fittings and proper sanitation. It would appear therefore that the time is rapidly approaching when the total demands of the area will only just be met by the available supplies from existing surface and underground sources. When that point has been reached it will be necessary to develop new sources of supply outside the London basin.

For these reasons the Board considered that the resources in the suggested area should be planned comprehensively and on a unified basis with a view to their pooling and their equitable distribution, and that future supplies should likewise be planned for the entire area on a long-term basis and in the expectation that schemes of considerable magnitude will have to be embarked upon within a measurable time, to make the position secure and ensure supplies sufficient to meet the expanding demands.

If the foregoing submissions are accepted, the only question would appear to be how the necessary planning can best be effected. It is evident that if the present system of a large number of separate water undertakings were to continue, or were to continue in a substantial degree, amended perhaps by such piecemeal amalgamations as might from time to time appear appropriate, the planning would have to be done by an external and supervisory Authority. That Authority would have to be either advisory or mandatory.

If it were to be advisory the Board felt that it would be ineffective. The White Paper referring to this aspect of the Regional Advisory Water Committees already set up stated: "They are handicapped by the fact that they rely entirely for their effectiveness on the goodwill of the individual undertakers."

If the Authority were to be mandatory, the Board were of the opinion that, with the large number of undertakings in the Greater London Area, its big population, and the anticipated large-scale development before referred to, carrying with it constantly changing water requirements, any procedure which involved continual applications to the supervisory Authority, the hearing of representations by various interested and independent parties, and possibilities of further delays imposed by appellate or quasi-appellate rights before the decisions become operative, would be found to be far too slow and cumbersome to deal satisfactorily with a problem of this complexity.

Whilst fully appreciating the merits of the Water Act, 1945, they felt that the compulsory procedure laid down therein, necessitating as it does recourse to Parliament in opposed cases where the opposition is not withdrawn, would be particularly open to these objections.

Amalgamations of existing undertakings. It seems quite clear that a considerable degree of amalgamation involving the disappearance of a number of the existing undertakings must occur. It is, however, probable that such amalgamations would be piecemeal and in some cases no doubt the compulsory procedure envisaged by the Water Act would have to be invoked. Moreover, even if a reduction in the number of water undertakings were so obtained, the difficulties would merely be reduced and not removed.

Three-tier structure. The establishment of a three-tier structure referred to elsewhere in this summary would, in the Board's opinion, be cumbersome, tardy and expensive.

Bulk Supply Board. The establishment of a Bulk Supply Board or the assignment to one of the existing undertakers of the dual role of a bulk supply authority and a distributing authority might be suggested as another way to deal with the problem. In the Board's view the engineering, financial and administrative difficulties inherent in this method so far as the London area is concerned would render it undesirable and probably impracticable.

One entirely new Authority. The only remaining course, therefore, would appear to be the setting up of an entirely new Authority as recommended by the Board.

3. *Suggested Constitution, Powers and Duties of the New Body*

The Board expressed the opinion that any new authority to be set up should be non-profit-making and should be composed of public representatives. After careful consideration of alternative suggestions as to the constitution of the proposed authority they arrived at the conclusion that it should be left either directly or indirectly in the hands of the local authorities.

Such an Authority would be able to distribute the available water fairly and would have the highly skilled specialist staff, the financial resources, and the experience, to regard the area as a whole, to plan adequately and far in advance, to act promptly and to carry through such development schemes, however large they might be, as from time to time might be found necessary. Research into technical matters relating to water supply and purification could be carried out on a scale and with a thoroughness impossible to small authorities, and standardisation of equipment and methods and bulk purchasing of stores would tend to lower costs. Most important of all, however, the cohesion, singleness of purpose, executive power, and flexibility in the use of resources resulting from unified control would be far greater than could possibly arise from a number of independent undertakings, however harmoniously they might endeavour to co-operate, or whatever directions for co-ordination might be given to them from a higher level.

The Board were satisfied from the experience already gained in the administration of a large area that there would be no difficulty from the point of view of engineering administration in an authority of the size contemplated. The financial and general administration would be entirely practicable, service to the consumer would certainly be not less efficient than at present and the consumers over the whole area would not be placed on average in a financially worse position. The integration of the various water supply undertakings into a single authority would be an advantage from the point of view of control and assessment of quality and in the maintenance of a high standard of purity.

With regard to the powers and duties of the new Authority, it would be sufficient for it to possess the usual powers and be subject to the usual obligations of a statutory water undertaker and to operate within the framework of the general code of

Water Law subject to such exceptions or additions as experience might from time to time indicate to be desirable. The integration of the various undertakings could probably best be carried out in stages in order to reduce to a minimum any disturbance caused by the transition.

Authorities supporting the proposals

The principles of the Board's proposals were supported by the County Councils of London and Middlesex, the Metropolitan Boroughs Standing Joint Committee, the West Ham County Borough Council and certain other authorities. The Leader of the London County Council, Lord Latham, in evidence before the Committee, expressed the opinion that the appropriate authority should take the form of a small *ad hoc* body appointed by the Minister of Health and responsible through the Minister to the House of Commons. Local authorities should, in the Council's submission, be given powers of representation both to the Authority itself and, if necessary, to the Minister, as to the provision of proper facilities, points of distribution, quantity, charges and kindred matters. The Middlesex County Council and the Metropolitan Boroughs Standing Joint Committee gave evidence in favour both of the Board's proposal for a single authority and of the principle that that authority should be a public representative body.

Opposition to the Proposals

(1) *Submission on behalf of the* 57 *undertakers*

A joint memorandum on behalf of 57 undertakers who were adverse to the Board's proposals was submitted. The general argument may be summarised under the following headings:—

(*a*) Geological;
(*b*) Engineering;
(*c*) Administration;
(*d*) Financial;
(*e*) Counter-proposal—a three-tier structure.

(*a*) *Geological.* A detailed investigation revealed that in the undertakers' areas there are potential surplus supplies in the Chalk and Lower Greensand, which would be more than sufficient to meet not only the normal increased demands of the existing population in those areas, but also the demands of the

decentralised population which may move there from the central London area. The hydro-geological conditions in the Chalk and Lower Greensand vary considerably in different parts of the London Basin, and an intimate knowledge of the characteristics and history of each area is required to ensure its efficient development for water supply. In the view of the undertakers, therefore, existing undertakers, or amalgamations of small adjoining undertakers, would be more competent to administer and develop their resources than an executive water authority for the whole of the suggested area.

(*b*) *Engineering.* In furtherance of the accepted principle that local resources of any particular area of supply should be developed for the use of the local population before an undertaker seeks a supply from elsewhere, the undertakers submitted that there must of necessity be a number of comparatively small pumping stations situated at no great distance apart for the extraction of water from the respective sites. Any new administrative body would have to deal with the state of affairs as existing and the establishment of larger units in replacement of small ones would not effect economy. There is, moreover, an essential difference between the engineering conditions in respect of the present area of the Metropolitan Water Board and those pertaining to the area of the 57 undertakers. In the case of the Board, reliance has to be placed to a large extent upon the river Thames, whereas with few exceptions the outside area derives all its supplies from underground sources. River-derived supplies involve large storage reservoirs and extensive processes of purification. Underground sources are obtained and delivered locally and in many cases sterilisation is the only safeguard necessary to ensure a high standard of purity.

(*c*) *Administration.* In the view of the 57 undertakers, the following difficulties would be attendant upon the engineering administration of the suggested area:—

(i) The heavy programme of works to be undertaken would make it impossible for the Chief Engineer and his immediate subordinates to give proper attention to the matters arising.

(ii) Administrative duties involving constant attention at the central offices would make it impossible for these officers

to keep in personal touch with the outside running of the undertaking.

(iii) It is possible that some of the best engineering talent would seek employment elsewhere and the present difficulty in recruiting sufficient experienced staff thereby become aggravated.

(*d*) *Financial.* The outside undertakers submitted that the average cost to the consumer of water supplied by them is lower than that of the Metropolitan Water Board.

(*e*) *Counter proposal: a three-tier structure.* The 57 water undertakers considered that by suitable amalgamations the number of undertakers within the Greater London Area should be reduced as soon as possible and if, and when, circumstances necessitate, similar amalgamations should take place in the further area lying within the London Basin and outside the Greater London Area.

To co-ordinate the resources of the integrations and their use, there should be a further integration so as to cover the area of the London Basin by a number of Joint Advisory Water Committees for the Greater London Area constituted in accordance with the Water Act, 1945, and such additional Joint Committee or Committees for the remainder of the London Basin as future developments may indicate to be necessary.

The co-ordination of the work of the Joint Advisory Water Committees should be in the hands of a Water Resources Authority comprising a small number of representatives of each Committee. This Water Resources Authority should report its recommendations to the Minister, by whom the Chairman should be appointed.

(2) *Submission on behalf of the County Councils.*

The County Councils of the administrative counties of Bedfordshire, Berkshire, Buckinghamshire, Hertfordshire, Kent and Oxfordshire made submissions to the Departmental Committee. Briefly, they expressed the view that adequate machinery for the planning of the suggested area is already envisaged by the Water Act, 1945, and that the administrative organisation which would be required under the Board's proposals would be cumbersome and that desirable personal

contacts between chief officials and smaller units would be impossible.

(3) *Other Submissions.*

Amongst other submissions made to the Committee, the following may be mentioned:—

(*a*) *Essex County Council and South Essex Waterworks Company.*

(i) *Waterless Essex.* The term "Waterless Essex" embraces the belt of the county stretching from south-west to north-east and bounded by the coast line, in which no further water in any reasonable quantity is likely to be obtained from underground sources. It includes the entire area of supply of the South Essex Waterworks Company. The Essex County Council and the South Essex Waterworks Company submitted that Essex presents a difficult problem, and that Metropolitan Essex should be treated as part of the Essex problem and separately from the remainder of the London area.

(ii) *Adjustment of limits of supply.* As a result of Acts passed in 1853 and 1861, the South Essex Company and the East London Water Works Company were each authorised to supply water in certain parishes in Essex, including East Ham, Barking, Ilford, Romford and Dagenham. The two Companies did not, however, supply water in competition with one another and a line of demarcation between their areas was agreed. As successors of the East London Water Works Company, the Board have complied with this line of demarcation and the Company therefore suggested that the position should be regularised and statutory effect given to the arrangement by repealing the powers of the Board east of the said line, and those of the Company west of it.

(*b*) *Guildford Borough Council, Godalming Borough Council, Cranleigh and Chiddingfold Water Company, Hambledon Rural District Council, and Hurtwood Water Company.*

On behalf of these undertakings it was submitted that they should together form a separate Water Board and should not be included in the proposed Greater London Water Area.

(*c*) *Bucks Water Board.*

The Bucks Water Board was established in 1937, the constituent authorities being the Buckinghamshire County Council, and the Aylesbury, Buckingham, Wing and Winslow Rural

District Councils. A portion of their area of supply is within the area suggested by the Metropolitan Water Board. The Bucks Water Board submitted that the inclusion in the suggested area of that part of the area now within the limits of the Bucks Water Board and the transfer of valuable sources of supply within those limits would inflict serious injury upon the Bucks Water Board and upon the inhabitants and consumers of water within their limits.

(*d*) *Thames Conservancy.*

The Conservators of the River Thames made representations to the Departmental Committee concerning a proposal made by the Board that the flow of river water should be reduced, in certain circumstances, below the statutory limit of 170 million gallons daily.

The Conservancy submitted (i) that the reduction of the statutory flow over Teddington Weir below 170 million gallons per day resulted in a loss of amenities of the river, and (ii) that the completion of the Kingston-upon-Thames power station would entail the abstraction of large quantities of water which would be returned to the river at a temperature necessitating the maintenance of a flow in the river estimated to be not less than 170 million gallons daily.

The Report

The public hearings closed on 23rd June, 1947. The Committee's report was issued on 31st March, 1948.

The following is a summary of the Committee's findings:

Resources and potential yield of the Area. The Committee discussed the sources of supply in some detail and stressed the view that the estimated reliable yield should be discounted for a number of reasons. After weighing up the uncertainties connected with the prediction of future demands, such as (i) the indefinite increase in the amount of water required by industry and agriculture; (ii) the unknown changes in distribution of population and industry in the area, and (iii) the uncertainty as to the amount of the increase in consumption as represented in gallons per head per day, the Committee expressed the opinion that the consumption would rise owing to the increased provision of water-using facilities in modern houses, the

establishment of new towns, the effect of district heating and the extension of water supplies in rural parts of the area.

The Committee were further of the opinion that, due regard being paid to the avoidance of waste, it is in the interest of public health that the consumption of water should increase, and that adequate provision should be made to meet greater demands.

Pooling of resources. On this subject the Committee said:

> "We are of the opinion that the resources of the area must be treated as a whole and we are convinced that the community of interest in the Greater London area and the geological unity of the Thames Basin demand the pooling of all resources and the treating of the problems of water supply in the area in co-ordination. Proposals recognising this fundamental fact must aim, ultimately, at effecting the pooling of both resources and costs, combined with the highest standard of efficient service."

This decision is a complete endorsement of the proposals put forward by the Board.

Major outside source. The Committee expressed the unanimous opinion that before water is brought into supply from major works involving an outside source, steps must be taken to exploit fully and rationally all the resources within the area. Because, however, of the length of time which is needed to construct major works, they felt that a detailed and immediate inquiry into possible outside sources should proceed simultaneously with investigation of the resources within the area, keeping in mind that development in the watershed of the river Lee may well render that river less suitable as a source of supply at no far distant date, and that steps should be taken now to formulate a scheme for a major supply from an outside source.

Inquiry into water resources and prospective demands. The Committee stated that "an exhaustive enquiry is urgently required into the water resources and prospective demands of the area." So far as the resources are concerned, it is difficult to ascertain what is meant because very complete evidence was given, and written information obtained, about the resources in the Greater London water area at the inquiry held by the Committee.

Control of private abstraction. With regard to the control of private abstraction of underground water, the Committee recommended that the provisions of section 14 of the Water Act, 1945, which prohibit the sinking of wells without a licence from the Minister in any area that may be scheduled, should be extended to the whole area.

Research on treatment of water. With reference to this subject the members of the Committee were unanimously of the opinion that the new Authority or Authorities should have the specific duty of engaging in research on treatment of water.

Control of Greater London water area by a single authority. While the Committee unanimously agreed that the necessity for some central water authority follows from the recognition that the area has a community of interest, is a hydrogeological unit and is rapidly approaching the limits of its internal resources of water, they were unable to agree on the constitution and powers of the authority or authorities to be established to give effect to these general conclusions.

The Chairman and Sir Frederick Alban recommended that since the future water supply of Greater London is an indivisible problem the new authority should be a single all-purposes authority with full executive powers over both sources and distribution. This proposal was originally put forward by the Board. The Board, however, also recommended that the single authority should consist of public representatives, whereas the Chairman and Sir Frederick Alban recommended that the new authority should be a small *ad hoc* authority of five full-time members and two part-time members; the five full-time members to be appointed by the Minister and the two part-time members to be appointed by him after consultation with the local authorities in the area.

The area recommended for the single authority was a little less than that suggested by the Board.

Control of Greater London water area by four Boards and a superimposed Central Water Authority. Sir Charles des Forges, Mr. F. J. Dixon and Sir Roger Hetherington considered that a single all-purposes authority could not administer efficiently

and economically such a large area as that proposed by the Metropolitan Water Board, and they recommended that a slightly smaller area should be divided into four, each part being controlled by a Joint Board, with an over-riding Central Authority which would have power to direct the four boards as to the development of new and existing sources within their respective areas and the giving and taking of bulk supplies. The constitution suggested for these authorities was as follows:

(*a*) A central water authority, with ultimate control over all sources, consisting of a Chairman and Deputy Chairman (both full-time) appointed by the Minister and 17 members appointed by the four joint boards from their members; 6 appointed by the Metropolitan Water Board, 3 by each of the other Joint Boards and one each by the Thames Conservancy and the Lee Conservancy Catchment Board.

(*b*) Four independent water boards for the distribution and administration of water resources, such boards to be of a representative character and that local authorities, including the County Councils, should be represented individually or in groups.

The three members also expressed the view that a considerable reduction could well be effected in the number of representatives on the Metropolitan Water Board and suggested a membership of between 30 and 40. For each of the other three boards they proposed a membership of 15 to 20 as reasonable.

This proposal was entirely contrary to that put forward by the Board, *viz.*, that the obligation for the supply to the suggested area should, in all its details, be the responsibility of one authority.

In the Board's view the proposed organisation of four water boards and a superimposed body would lead to great difficulties, and the arguments against this suggested organisation were well set out in the report of the Chairman and Sir Frederick Alban.

It is not quite clear from the report of the three members where the duties of the Central Water Authority would end, as it is stated that it should not "concern itself with distribution and administration." No reference is made to abstraction, storage or purification, but presumably it was intended that

these functions should be part of the duties of the four water boards.

Conclusion

The Board considered the Report with care. It was a matter for satisfaction that the Committee endorsed the view that the resources of the area should be pooled and problems of water supply in the area co-ordinated. It was a matter for regret that the Committee could not agree on the means to give effect to their conclusions. From the engineering point of view the Board's policy of constructing large additional works at the earliest opportunity was completely vindicated.

CHAPTER XXIX

External Relations

Government Departments

THE Minister of Housing and Local Government is responsible to Parliament for water supply, among other local government services, and in numerous cases his authority is required before works can be undertaken or public money spent by statutory water undertakers. The Board are thus brought into close contact with this Department of State.

By section 28 of the Metropolis Water Act of 1902, the Board are required to submit an annual report of their proceedings to the Minister, who lays it before Parliament. These annual reports contain much information concerning all branches of the Board's work and a large number of statistical appendices from which it is possible to obtain an outline of the Board's progress.

The plans of other authorities (e.g., New Towns) frequently involve important matters of water purification and control which make close liaison between the interested parties indispensable. This is achieved through the medium of the Ministry of Housing and Local Government and in all such matters the Board, whether members or officers, invariably find a spirit of understanding and goodwill.

Thames Conservancy

There is no need to emphasise that close and cordial relations exist between the Board and the Conservators of the River Thames.

As noted elsewhere in this review the Conservancy, by reason of their responsibility for the Thames above Teddington Weir, exercise control over the Board's principal source of supply, and in a time of crisis the closest collaboration in all respects is observed between the two bodies in seeking a solution of any difficulties which may arise.

This collaboration is materially assisted by the fact that the Conservancy appoint one member to serve on the Board and the Board appoint four of the Conservators. It is of interest to record that upon consideration of the Thames Conservancy Bill of 1950 by a Select Committee of the House of Lords, the Chairman of the Committee, Lord Winster, remarked:

> "The Committee . . . also wish me to say that they have noted with pleasure the very friendly relations which exist between the Conservancy Board and the Metropolitan Water Board."

Lee Conservancy Catchment Board

The River Lee provides about one-sixth of the Board's supply. The catchment area has undergone considerable development in recent years and is even now forming the site of a number of new towns. The Lee is not a large river and problems of drainage have created great difficulties in the maintenance of quality of the river water. The Lee Conservancy Catchment Board, who administer the river, have without fail supported the interests of the Water Board and the sympathy and co-operation characterising their activities must be recorded.

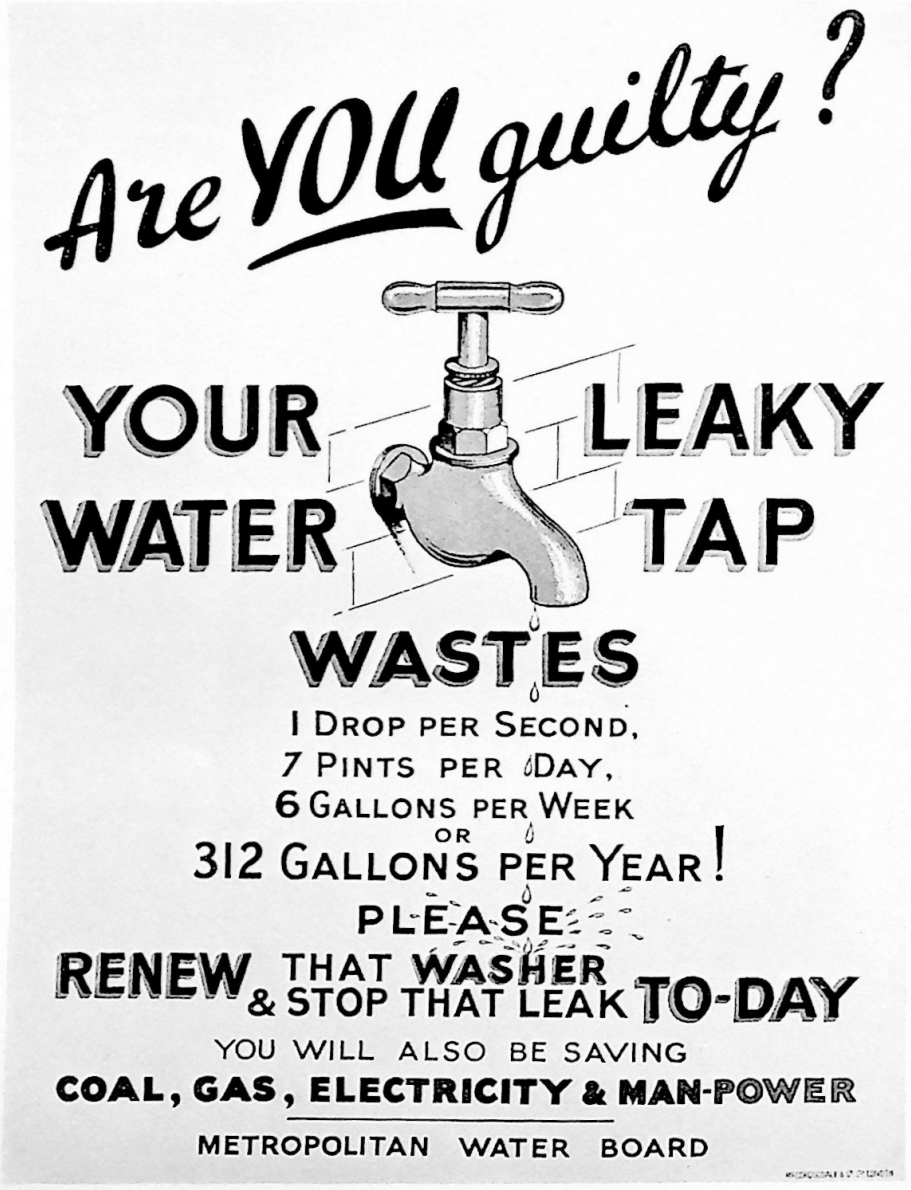
The Lee Conservancy Catchment Board appoint one member to serve on the Water Board and the Board appoint two members of the Catchment Board.

British Waterworks Association

The principal waterworks undertakings of the United Kingdom formed in 1912 a body called the Municipal Waterworks Association so that they might have the advantage of centralised information and influence in dealing with important questions of general interest which constantly arise in Parliament and elsewhere. Membership of the Association was open to Municipal Corporations possessing waterworks in the United Kingdom and supplying water to populations of over 50,000 inhabitants.

The Board joined the Association and appointed the Chairman of the Board and the Chairman of the Works and Stores Committee as their representatives. The first annual general meeting of the Association was held in October, 1912, at

THE BOARD'S PUBLICITY EXHIBIT



PUBLICITY, 1943

the Water Board's offices under the Chairmanship of Mr. E. B. Barnard, Chairman of the Board, who was elected the first President of the Association.

In 1920, the Association was incorporated and its name changed to the British Waterworks Association (Inc.).

The Association's membership now includes virtually all the water undertakings in Great Britain. The Board appoint five representatives.

Professional Bodies

Many of the Board's senior officers are members of professional institutions or societies and as such contribute in no small degree to the furtherance of their own special branches of knowledge. In some cases the Board make monetary contributions to scientific and other bodies under the powers conferred by their Acts of 1927 and 1939.

Publicity and Public Relations

The aim of publicity is usually to increase sales or service. In the case of the Board it is rather the opposite, that is, to bring home to consumers what is involved in providing a plentiful and pure supply of water and by so doing to enlist their co-operation in avoiding waste and thus to effect economy in capital and running costs. This is always important.

There is also the short term aspect, which assumes special significance in times of drought or shortage for any other reason. The object in such cases is primarily to conserve the resources in hand, because although the Board have many large reservoirs, these can be seriously depleted when the natural river sources of supply (the Thames and the Lee) begin to fall off.

Prior to the last war the Board's publicity was confined, in the main, to this second aspect, and there is little doubt that it met with considerable success. During the severe drought of 1934 slogans such as "Use less water," "Save water," and the like became almost household expressions and contributed in no small degree to an immediate and substantial reduction in consumption.

The stern necessities of the last war, however, made it a matter of national concern to avoid all forms of waste, including waste of water. By so doing consumers could reduce the con-

sumption of coal and other commodities and at the same time make more water available for urgent needs which had to be met. The Board co-operated with the Ministry of Fuel and Power to this end.

Then came the drought of 1944 when drastic measures were found to be essential to conserve the Board's dwindling resources. Appeals were made to the public through the Press, by letters and circulars, and even by personal calls by members of the staff. These met with an immediate and heartening response, and although severe restrictions on the use of water were necessary for a time, the co-operation of the water consumers undoubtedly assisted in reducing the period for which they had to be imposed.

Immediately after the war the demand for water began to rise sharply and the need for new works became even more apparent. These however cost large sums of money and in some cases take years to complete. The need for economy in the use of water had to be viewed in this light. One means of effecting it was by enlisting public interest in the work of the Board and securing co-operation in what is, after all, a matter of common interest. The post-war publicity measures therefore assumed a new aspect. They included the following forms:

(i) Visits to works by members of constituent authorities at the invitation of the Chairman of the Board.
(ii) Organised visits to the works by parties of scholars, student nurses and others.
(iii) The display on prominent sites of a specially constructed publicity exhibit.
(iv) The preparation of a documentary film of the Board's work.

Some remarks on each of these will indicate their popularity and scope.

The Chairman's visits, as they are habitually called, were initiated by the late Chairman, Mr. Harold Gibbons, O.B.E., in order to acquaint the members of the various constituent authorities with the Board's work. The practice has been continued by the present Chairman, and during the Festival of Britain the scope of these visits was widened to include distinguished visitors from overseas and members of

certain of the professional institutions holding conferences in London at the time.

Organised visits to works by members of the public are a very popular feature of the Board's activities. Parties are met by guides and are conducted over the selected station, so that as many of the engineering and purification processes as possible shall be seen in their proper sequence. For this reason visits are confined to works where the processes are conveniently grouped in one place, i.e., Hampton, Kempton Park and Walton in the Thames valley and Stoke Newington in the valley of the Lee.

Some 33,000 persons have made use of these facilities since their introduction in 1948.

A publicity exhibit was constructed by the Board's staff in 1948, and has since been displayed at a number of important sites in the Metropolis, such as the Horse Guards Parade, the Zoological Gardens, Regent's Park, Charing Cross Underground Station and Cheapside. Improvements have, of course, been incorporated from time to time and the exhibit is generally regarded as of high quality. Unlike visits to works, where the public come to the Board, the success of this lies rather in the Board going to the public. A photograph is reproduced opposite page 326.

The Board's film "Every Drop to Drink," was made in 1947–48, and has been extensively used by schools and institutions throughout the Board's area and beyond. Copies have been acquired by the Central Office of Information, the Foreign Office and a number of Departments overseas. In 1949 the film was selected for use by the British Delegation to the United Nations Scientific Conference on the Conservation and Utilisation of Resources, held at Lake Success.

Fishing

Fishing in the Board's reservoirs has for many years afforded anglers much pleasure and recreation at a modest price. These inland lakes, some of them of considerable size, yield a variety of fish, and over 27,000 visits by day and season ticket holders are made in a year to the reservoirs at Barnes, Barn Elms, Walton and Walthamstow. In addition, certain of the Board's waters are let to angling societies. Ornithologists,

too, find much to interest them, especially at Walthamstow, where many kinds of birds may be observed in their natural surroundings. (See photographs facing pages 288 and 289.)

Assistance to Other Authorities

From time to time the Board have been able to assist other water authorities in periods of drought or other emergency by the provision of mobile purification units and tank waggons or by affording supplies of water in bulk.

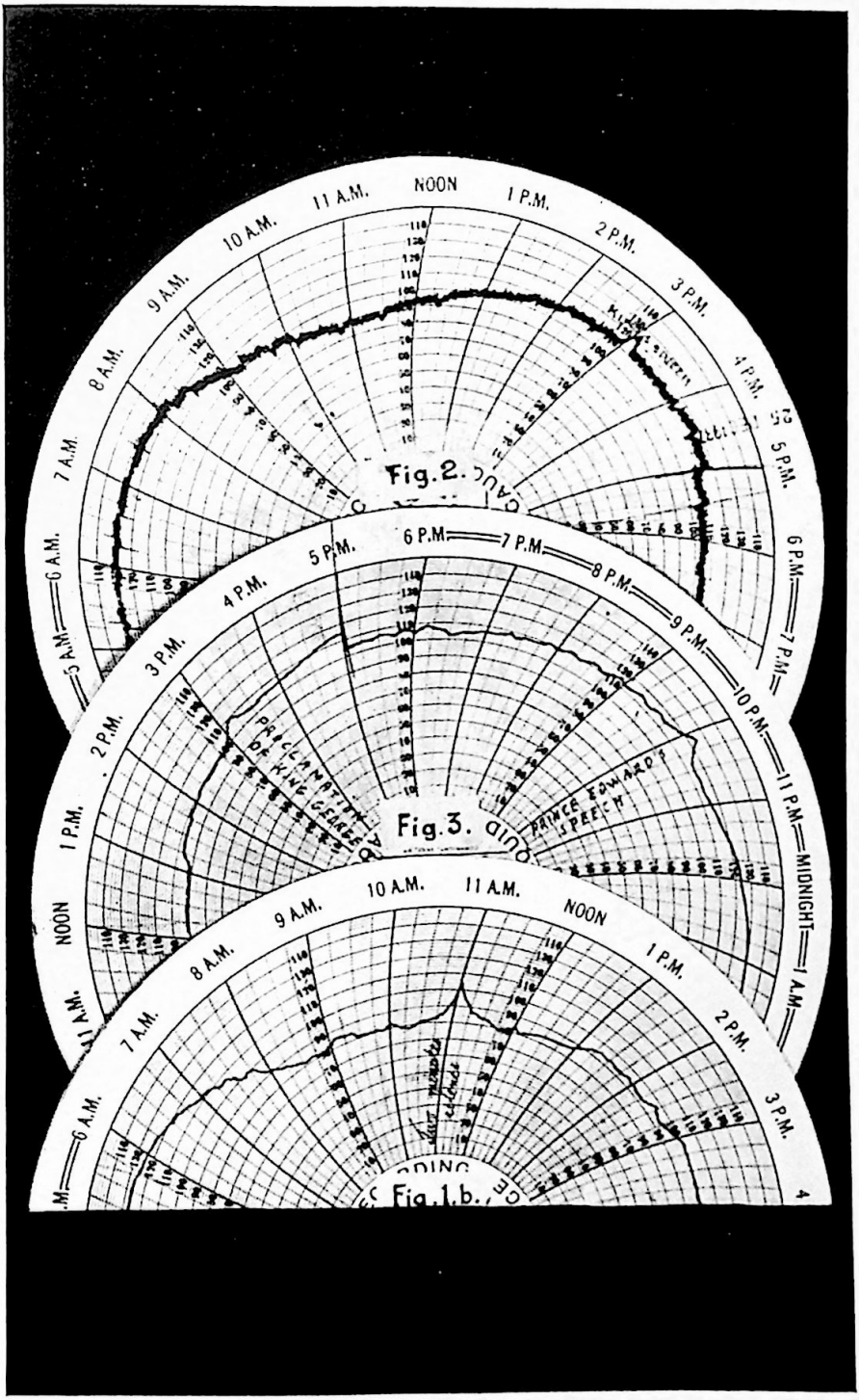
During the floods which occurred in the Fenland in 1947, and near Berwick in 1948, portable pumping machinery and operating staff were loaned to assist in pumping water from the affected areas. In February, 1953, consequent upon the disastrous flooding of eastern England, the Board's help was again enlisted for the provision of plant and staff and also in connection with the examination of samples and advice on water treatment.

Public Events and Water Supply

For a history of major public events few people are likely to look to their water undertaking. The use of water, however, is so bound up with the lives of the human beings forming a modern community that the public's absorption in an historical event or even an entertainment can often be gauged by the way in which they have turned the water off during the event, either in the home, the office, or the factory. This "turning off" increases the pressure in the mains which is automatically recorded on charts. The kind of incident or event that lends itself to this recording has generally been the subject of a broadcast. Amongst the many records which the Board possess, not the least interesting are those which show the effect on water pressure and consumption of such occasions as the Royal Broadcast on Christmas Day or the Two Minutes' Silence.

The illustration opposite this page is of pressure charts taken from a part of the distribution system and is typical of the whole area.

It will be seen that whereas the pressure in the mains as indicated by the thick wavy line is conforming to a definite pattern throughout the period shown, a sudden break occurs at the time of the incidents recorded. The public have left their other pursuits for the moment and are listening. The notes on the charts were made by the local staff at the time.



PUBLIC EVENTS AND WATER SUPPLY

Pressure charts showing the effect of (*a*) The Royal Broadcast, Christmas Day: (*b*) The Abdication Speech and the Proclamation of King George VI: (*c*) The Two Minutes' Silence

"AND SO TO BED"
The Aquarius Players, April, 1949

CHAPTER XXX

Staff

At the appointed day the Board's staff numbered 3,463, comprising 556 officers and 2,907 workmen. Today the figure is 6,400 (1,617 officers and 4,783 workmen) distributed as follows :—

Department	Officers		Manual Workers	Total
	Salaried	Unestablished		
Clerk of the Board ...	74	4	26	104
Chief Engineer	731	45	4,722	5,498
Director of Water Examination	40	1	29	70
Treasurer and Comptroller	633	42	6	681
Solicitor and Parliamentary Officer ...	22	—	—	22
Surveyor	21	4	—	25
Total	1,521	96	4,783	6,400

Included in this staff is a wide range of professions, trades and skills, some of which are common to public enterprise whilst some are peculiar to the water industry or to the Board's undertaking in particular.

The increase in staff which has taken place since 1904, is attributable to a number of factors amongst which are the greater volume of work and the more exacting standards demanded than formerly.

The Transition Stage

When the Board started, the twin problems of (1) the best use of the transferred staff and their continuance in existing

or analagous duties and (2) the setting up of a new organisation with new duties, had to be solved concurrently. Clearly, some of the former posts would, in due course, become redundant but the considerable experience and ability of many of the companies' officers would find new and often larger openings in a unified undertaking.

Thus, the first Chief Engineer (Mr. Bryan) and his deputy (Mr. Restler) had come over from the East London Water Works Company and the Southwark and Vauxhall Company respectively. The first deputy comptroller (Mr. Newton) who became Accountant in 1908, had held the position of Accountant with the Southwark and Vauxhall Company. On the setting up of a Supervisor's department in 1919, the choice fell on Mr. F. W. Drake who had had similar experience with the New River Company before the appointed day. Such examples could be multiplied.

The last of the transferred officers and servants to leave the Board's service were Mr. M. W. Piggott, formerly with the West Middlesex Company, and Mr. J. W. Messingham, formerly with the Southwark and Vauxhall Company. Both retired in 1951 and were invited to attend a meeting of the Board on 22nd June, 1951, when the Chairman expressed the appreciation of the Board for their long service and best wishes for a happy retirement.

With the transfer of the companies' staffs the Board inherited a variety of practices and customs, some of which had existed for many years. The scales of salaries and wages paid by the companies were different, emoluments of office were different, privileges were different. The Chief Engineers received salaries which, with emoluments, ranged from £950 to £4,850 per annum. They were, in addition, allowed to engage in private practice. Collectors of water rate received in some cases commission, in others a fixed sum, and in others part commission and part fixed sum, the remuneration being in at least one case about £1,000 a year whilst in others it was not much more than a quarter of that amount.

Early consideration was given to these and similar matters in order to ensure, as far as was reasonably possible, equitable treatment throughout the service.

Officers

Prior to 1914 it was the practice to appoint new entrants as boy clerks at 15 years of age, the Board holding their own examinations for that purpose. In 1914, however, this system was reviewed and it was decided to adopt a list of qualifying examinations which, with appropriate additions and alterations, is still operative as a standard for permanent appointments. The minimum age for appointment to the permanent staff is now 18 years.

The Board encourage post-entry study. In 1947 provision was made for granting, in appropriate cases, a pensionable allowance of £25 per annum to officers in receipt of salaries up to a specified maximum, who pass any one of an approved list of final examinations. Most of the staff in senior positions hold university degrees, diplomas or other suitable qualifications. In the majority of cases they are also members of an appropriate professional institution. It is not unusual for the Board's officers to serve on Government and other Committees and some are leading authorities in their own spheres.

It is perhaps inevitable that in a service such as the Board's there should be some outward flow of officers to more attractive positions elsewhere. Of recent years the movement has become more marked and is at the present time giving rise to some concern.

In 1909, the Board approved a scheme for the establishment of a Superannuation and Provident Fund for the benefit of the officers and servants of the Board in accordance with the provisions of the Board's Various Powers Act of 1907. The scheme was primarily intended for personnel appointed by the Board who were not entitled to superannuation, although the Board had the power to grant such allowances under the Superannuation (Metropolis) Act, 1866. The officers and servants who were transferred from the companies were, with certain exceptions, entitled to superannuation. The scheme was framed upon the contributory principle, the initial contribution by the Board amounting to approximately £9,000. Revisions have taken place from time to time to include, *inter alia*, the provision of death benefits, the combination of a lump sum payment with a lower pension, and the allocation by a contributor of part of his pension to his widow.

The amount of the invested Fund at different periods was as follows :—

Year ending 31st March.	Amount of Invested Fund		
	£	s.	d.
1914	85,678	1	9
1921	276,866	12	7
1931	1,066,098	15	8
1939	2,202,300	11	11
1952	4,661,647	10	2

In 1947, regulations were adopted under which officers and employees are given the opportunity of submitting suggestions relating to the working of the undertaking. The scheme provides for suggestions to be considered by the Chief Officer concerned in consultation with the Chairman of the controlling Committee, and for the granting of monetary awards in appropriate cases.

All officers and employees, whether permanent, temporary or auxiliary, leaving the employment of the Board after 20 years' service are presented, on request, with a certificate on vellum, under the seal of the Board, and emblazoned with the Board's Coat of Arms, as evidence of their association with the work of the Board. The award is made on the recommendation of the appropriate Committee in each individual case. In practically every case of retirement a request is made for one of these certificates.

Staff Association

A Staff Association was formed in 1904, originally for "the promotion of good fellowship among members of the staff, the furtherance of social and literary functions, and the encouragement of such branches of sport and recreation as may be found desirable."

Within a year the Association's membership was over 400. To-day nearly all the members of the salaried staff belong to it.

The Association found the Board very willing to provide such facilities as were possible for the furtherance of its activities. In 1908, the surfaces of the service reservoirs at Honor Oak and Fortis Green were made available for sports purposes,

followed within a year or two, by similar facilities at other works. With the progress of years the Association's interests and activities extended far beyond those originally envisaged until today they include practically all aspects of service.

In 1920, the Association put forward a proposal for the setting up of a "Joint Council for the Administrative, Technical and Clerical Service" along the lines envisaged by the Whitley Report. After some modifications the scheme was agreed to by the Board and came into operation the following year under the name of the "Advisory Joint Committee of Management and Salaried Staff." In 1945, its title was changed to "Advisory Joint Committee of Members and Officers." The Committee now consists of seven representatives of the Board and seven representatives appointed by the Staff Association, with a Chairman from one side and a Vice-Chairman from the other. The Committee considers general conditions of service, including pay, but does not deal with questions of purely individual discipline, promotion or efficiency. The decisions arrived at are subject to ratification by the Board.

Facilities have been provided for social, sporting and literary activities in many directions. In addition to cricket, football, hockey, golf, lawn tennis, badminton and athletics, the Association caters for swimming, sailing, shooting, chess and philately. A variety of trophies, presented by past and present members of the Board and of the staff, are competed for annually.

Amateur dramatics came on the scene in 1933, when the Aquarius Players held their inaugural meeting. In April of the following year the first production, *A Damsel in Distress*, was staged at the King George's Hall, Caroline Street. This was an immediate success and the Players have continued to provide dramatic entertainment of a high order at regular intervals since that date, apart from an enforced suspension of their activities during the Second World War. Other forms of entertainment are also provided by the Entertainments Committee of the Staff Association. They include concerts, dances, an annual arts and crafts exhibition and annual horticultural shows.

When the present Head Office was built, provision was included for dining facilities for the staff, the dining room being first opened for the service of meals on the 10th June, 1920,

just a fortnight after the inauguration of the new offices by Mr. E. B. Barnard, Chairman of the Board. The service provided by the Dining Club proved of great value to the staff, and the business increased so rapidly that when the building was extended in 1934 an entirely new and more spacious dining room was included. A new dining room for members of the Board was also constructed at the same time. Service is provided by the Staff Association.

The Association's magazine *Aquarius* has maintained its production since 1904, and is the recognised medium for the conveyance of news and views throughout the service. This is an important function, particularly as the offices and works of the Board are spread over a wide area.

In 1908 a Benevolent Fund was created by the staff for the purpose of providing pecuniary or other assistance in necessitous circumstances to members of the Fund and to dependants of members or deceased members in consequence of war service or other cases of misfortune. A further step in the same direction was the establishment in 1923 of a Service Hospital Fund. The object of the Fund is to enable contributors to make such provision as will assist them or their dependants whilst receiving treatment as in-patients at hospitals and other institutions. Since the inception of the scheme membership has risen from 2,180 to 4,850 and some 32,500 claims have been met, the total benefit paid exceeding £56,000. Membership of the Hospital Fund is open to officers and employees. Contributors may continue membership after retirement.

Employees

The 4,800 employees comprise nearly 100 grades. They include 1,250 labourers and trenchmen, 466 turncocks and assistants, 315 inspectors, 228 stokers and boiler cleaners. At the other end of the scale are 1 lock-keeper, 1 leading well-hand and 1 jointing instructor.

Prior to the first World War wages, hours of work and working conditions generally were settled through the normal Committee system on representation from the appropriate Unions or accredited organisations of employees. Towards the end of 1918, however, following the Whitley proposals, a National Joint Industrial Council for the Water Industry

was established—the first of its kind to be formed in connection with municipal and public utility services—and this machinery, together with the appropriate District Council, has since become the recognised means for the regulation and settlement of these matters.

In common with labour generally the working week is now about two-thirds of what it used to be in the early days. In 1914 the average number of hours varied between 54 and 72 per week, the commencing time being in most cases 6 a.m. In 1919 the Board reduced them to 47 hours for day workers and 48 hours for shift workers, the commencing time for the former being altered to 7.30 a.m. In 1947 the working week was again reduced to 44 hours for all grades.

Cost-of-living adjustments of the rates of pay are, with few exceptions, made in accordance with the decisions of the National Joint Industrial Council. During the Board's life there have been introduced many new paid allowances relating to various features of the conditions of employment applicable to the Board's employees. In 1914 the labourer's rate, which is taken as the base rate of the structure, was 28 shillings per week of 54 hours. In 1937 a minimum of 60 shillings was introduced (for a 47 hour week). At the end of 1945 this rate was fixed at 66 shillings plus a war wage of 24 shillings as part of a new graduated wage structure brought into effect by the Board. In October, 1952, the labourer's basic wage was increased to 3s. 1¼d. per hour, or an equivalent of 136s. 7d. per week, all wages now being consolidated on an hourly basis, instead of a weekly basis as hitherto, to accord with general industrial practice.

The average wages bill paid by the Board amounts to about £40,000 per week, or £2,080,000 per annum.

In 1907 the Board set up a panel of medical officers to provide medical attention for employees in cases of sickness, accident, etc. The area was, at an early stage, divided into 40 districts for the purpose, but by 1947 the number of districts had been increased to 127. This system continued until 1948, when it was terminated on the inception, in July of that year, of the National Health Service. The services of a medical adviser, (the Chief Medical Officer) are still retained.

By reason of the nature of their duties it is necessary that

some grades of employees should reside on or close to their work (for example, engine drivers at certain stations and turncocks and their assistants). To this end it is the Board's policy to provide housing accommodation where possible and where this is not possible to pay a rent allowance based upon a scale of "standard rents" which are graduated according to the grade of employee concerned. At the present time over 200 employees occupy Board's houses and in addition rent allowances are payable in more than 300 cases.

The Board have always recognised the importance and the value of properly constituted machinery in relation to matters affecting the welfare of their staff. In 1946, after the repeal of the Trades Disputes Act, the following notice was issued:

> "Wages and conditions of employment in the Board's service are regulated through the Joint Industrial Council and other voluntary machinery established by Employers' Organisations and Trade Unions.
>
> "The Trade Unions represent all classes of the Board's employees and collective agreements secured cover all the employees in the classes affected.
>
> "The Board recognise that this system of collective bargaining is the best method of settling wages and working conditions. It operates for the benefit of all their employees and helps to promote smooth working arrangements. It is, therefore, to the advantage of all concerned that every employee of the Board should be a member of a Trade Union."

The Board attach much importance to the adequate training of their "outdoor" staff and have, over a number of years, provided facilities and assistance in this direction.

Prior to 1939 the Board's jointers were engaged principally in the laying and repair of small mains, the corresponding work on large mains being left to the pipelaying contractors. In 1940, however, it was considered desirable that the Board's staff should be trained in joint-making on mains of all sizes and types in order to meet any need which might arise under wartime conditions and a "jointers' school" was accordingly set up at the Willesden works. The courses were subsequently extended to include elementary plumbing and pipe fitting. The facilities so provided have also been used by other undertakings,

by the pipelaying contractors and, during the war, by the Army. The number of attendances at complete courses since 1940 have been as follows:

Joint-making	1,389
Elementary plumbing ...	829
Pipe fitting	686
Total 1940–1952 ...	2,904

In addition to the foregoing, instruction is now given in the use of different kinds of plant such as thrust-borers, under-pressure drilling, tapping machines, etc.

A special training course for inspectors was started in January, 1942, and has continued successfully since. The course originally consisted of two parts, the first involving attendance at London County Council institutes and the second, lectures on subjects relevant to the inspectors' work. A third part was added later when arrangements were made for lectures and demonstrations at Willesden, more particularly on the work of the distribution section as a whole. The first part of the syllabus, that at the Institutes, usually occupies one half-day a week for about 8 months. The second part usually extends over about 18 weeks. The Works and Stores Committee have stipulated that to qualify for promotion to the grade of inspector, class I, employees must obtain a first-class pass in parts A and B, but those in the service before 1941 were exempted from reaching this standard in part A.

Since the training courses commenced 401 inspectors have taken part A at the L.C.C. Institutes and 349 part B. Great keenness has been shown by the personnel taking the courses and there is no doubt that considerable benefit is derived by the Board as well as by the men themselves.

The Staff and the two Wars

The reader of this Review cannot fail to observe the effects of the two wars on the progress of the undertaking. The calling up of men, some of them with years of experience, and the consequent inevitable reduction in the number and the dilution in the quality of the staff available to carry on, left their marks even after the emergencies had passed. Here, in this chapter,

the emphasis is rather on the impact of these events on the Board's personnel.

The names of the 170 who fell during the first War are inscribed on a tablet inside the main entrance of the Board's Central Office. The memorial was unveiled by Field-Marshal Earl Haig on 10th April, 1920. Immediately adjacent to it is a memorial to the 89 who died during World War II. This memorial includes also the names of one member of the Board and 27 of the staff who lost their lives during air attacks. It was unveiled in 1948 by Mr. Harold Gibbons, O.B.E., who at that time was Chairman of the Board.

The Board treated the serving members of their staff generously throughout both Wars by paying in nearly all cases the balance between the service pay and salaries or wages. This provision was of very great value in helping men with families or other dependants to fulfil their obligations free from anxiety during their service with the forces.

The Home Guard

Under the Defence (Local Defence Volunteers) Regulation of 17th May, 1940, which was the statutory authority for the Local Defence Volunteers, as they were then called, the Board were authorised to raise a battalion from their staff and employees, with the primary object of affording protection to the Board's works.

In response to an appeal issued by the Chairman of the Board, enrolments from all departments were promptly received. By the end of June, 1,200 volunteers had been enrolled and four companies were formed:

"A" Company, covering the northern and eastern areas of the undertaking.

"B" Company, covering the Kent area.

"C" Company, covering the River Thames stations and Brixton and Battersea.

"D" Company covering the Head Offices and the western area.

Commander E. E. Blackwell, R.N. (Retd.), at that time the Board's Air Raid Precautions Officer, first commanded the Battalion, but owing to the increase in his A.R.P. duties, he

resigned in February, 1941, and the Board's Surveyor, Mr. C. D. Shott, M.C., took over the command, with the rank of Lieut-Colonel.

The Battalion, under its official title, *viz.*, 39th County of London (M.W.B.) Battalion, was reorganised into six companies.

The strength of the Battalion gradually rose to 2,000 and during its lifetime over 4,500 members were enrolled. It was thus one of the largest in the London District, and in its role of guarding the Board's undertaking, covered one of the largest areas, *viz.*, over 500 square miles. The original defence scheme approved by the Military Authorities arranged for sixty-six of the Board's stations to be guarded in emergency. Although the majority of London District H. G. Battalions did not maintain nightly guards, the Board's Battalion throughout the four-and-a-half years provided such guards at all principal stations.

Throughout the heavy raids of 1940 and subsequently during the "Flying Bomb" and "Rocket" activity, the members of the Battalion rendered much assistance in dealing promptly with incidents which arose from enemy action—e.g. at New River Head, Lee Bridge, Stoke Newington, and other stations.

The "stand down" of the Home Guard was ordered by the Government to take place on 1st November, 1944. The strength of the Board's Battalion at this time was 1,712.

A "Farewell" Battalion parade was held at the Albany Street Barracks on 29th October, 1944, the Chairman (Mr. Henry Berry) and other members of the Board being present. The Battalion was represented in the final parade at Hyde Park when His late Majesty King George VI took the salute.

Special mention should also be made of the services rendered by the staff and the men employed by the district pipelaying contractors during the last war. As will be seen from the brief account on the Second World War, the Board established and maintained a highly efficient organisation for ensuring the supply at all times, but however excellent the arrangements they could not have fully met the situations which sometimes arose had it not been for the willing and determined efforts of all concerned.

During the worst air raids many hundreds of mains of all sizes were broken almost nightly. Very often large mains were damaged in the same crater as gas mains and apparatus of other undertakings. Not only had repairs to be carried out under very trying conditions, but in most cases alternative arrangements had to be made to keep the supply going in the meantime to the consumers affected. Working round the clock at one time threatened the health of the staff and enforced rest periods had to be introduced to prevent breakdowns. Considerable personal sacrifice was made during the critical days of aerial attack and although it is not possible in these pages to include a list of names of the officers and employees concerned, the Board's (and through the Board, the public's) appreciation of their services should not go unrecorded.

Conclusion

THE foregoing chapters have attempted to delineate the principal features of the Board's management of London's water supply through the past 50 years, and to give an account of their stewardship. It is largely a story of expansion and progress.

During the period the daily supply has risen from 220 million gallons to 320 million gallons. The supply per head per day which was about 34 gallons in 1904 is now nearly 50 gallons. It needs no great stretch of the imagination to realise that with this rising consumption and with the immense amount of building and rebuilding of London which has gone on, the Board has not stood still. The construction of huge reservoirs, the laying of large mains, the erection of new filtration and pumping stations and the remodelling of existing ones, the sinking of new wells—this work has proceeded with a minimum of commotion and, for the most part, without the majority of people knowing much about it.

A striking feature has been the increasing dependence of the whole area upon the River Thames. Whereas in the early days of the Board the eastern parts of London were receiving rather less than 10 million gallons of Thames water, today the figure is about 43. In the case of the Kent area, which in 1904 was entirely dependent upon wells, the infusion of water from the Thames valley works has steadily increased and is now about 11 million gallons per day.

Concurrently with these operations, the Board have been active in reducing waste of water, whether from their own system or through consumers' water fittings. This, although less spectacular than the building of new works, is very important, for it enables the Board to use the limited storage accommodation to greater advantage and diminish to that extent the necessity for large and expensive new construction, whilst at the same time reducing running costs. This was never more important than it is today.

The work of the examination and purification of London's water has undergone changes amounting almost to transformation. Some of the methods of treatment adopted in the early days have been superseded whilst others have, with the progress of scientific knowledge, taken on a new significance. New methods and techniques have been introduced. The tests imposed and the standards demanded are more exacting now than they were formerly and it is gratifying to record that the water as delivered to consumers is purer than ever before.

In matters of finance too, the Board's achievement has been considerable. The purchase of the undertakings of eight water companies, each of them comparable in size to that of a large town, the equalization of charges throughout the area and the financing of new works, all involve highly complex considerations. It may be observed that something like 45 per cent. of the Board's income is consumed on the payment of debt charges and taxation, leaving only eleven out of every twenty shillings for the primary purpose of supplying water. But the cost of water to an average household today amounts to little more than one shilling a week.

The undertaking was put to the severe test of war. It came through with credit. But as with the national so with the Board's economy, the post-war period has been one of slow recovery from the effects of the past and the gathering of strength to meet the future.

The Board—members, officers and workmen—are not unconscious of their responsibility, but may surely take legitimate pride in the achievements of the past. They face the future with confidence and determination to overcome every problem, not perhaps with ease but with credit to themselves and satisfaction to the water consumers whom they serve.

Chronological Table of Chief Events

1902 ...	18th December...	Metropolis Water Act passed.
1903 ...	2nd April ...	First meeting of the Board.
	26th October ...	First meeting of the Court of Arbitration.
1904 ...	24th June 25th July	The "Appointed Days" for transferring the undertakings of the Metropolitan Water Companies to the Board.
1907 ...	13th April ...	Inauguration of the "Knight" and "Bessborough" reservoirs, Walton.
1909 ...	5th May ...	Honor Oak service reservoir inaugurated by the Lord Mayor of London. (The "Beachcroft" reservoir.)
1911 ...	10th June ...	Walton pumping station inaugurated by Rt. Hon. John Burns, M.P., President of the Local Government Board.
	4th November ...	The "Island Barn" storage reservoir, Molesey, inaugurated by the Lord Mayor of London, Rt. Hon. Sir T. Vezey Strong, K.C.V.O.
1913 ...	15th March ...	Inauguration of the "King George's Reservoir," Chingford.
1914 ...	June	Abandonment of the "Round Pond" New River Head.
1920 ...	27th May ...	Formal opening of the Central Office, New River Head.
	June	Report of the Departmental Committee on the provisions and effect of the Metropolis Water Act, 1902 (Monro Committee).

1921 ...	Summer	... Drought.
1923 ...	27th February	... Report of the Royal Commission on the local government of the Administrative County of London and the surrounding districts (Ullswater Committee).
1925 ...	13th June	... Inauguration of the "Queen Mary Reservoir," Littleton.
1926 ...	19th July	... Inauguration of the Walton filtration works by Rt. Hon. Neville Chamberlain, M.P., Minister of Health.
	19th August	... The "statutory minimum flow" of the Thames (170 m.g.d.) came into force.
1929 ...	24th October	... Inauguration of the new works at Kempton Park by Rt. Hon. Arthur Greenwood, M.P., Minister of Health.
1932 ...	15th June	... Inauguration of the remodelled Deptford works.
	1st November	... Inauguration of the new works, Surbiton pumping station, by Rt. Hon. Sir Hilton Young, C.B.E., D.S.O., D.S.C., M.P., Minister of Health.
1934 ...	Summer	... Drought.
1936 ...	Midsummer	... Lease of the Hampstead and Highgate Ponds from the Corporation of the City of London expired and not renewed.
1938 ...	17th October	... Laboratories at New River Head opened by Rt. Hon. Walter Elliot, M.C., M.P., Minister of Health.
1939 ...	3rd September	... War.
1944 ...	Summer	... Drought.

1945 ...	Autumn ...	... Hampton primary filters brought into use.
1946 ...	March ...	... Filtration works at New River Head closed down.
1947 ...	March ...	... Flooding of the Lee Bridge works.
	2nd June	... Daily supply reached the record figure of 428 million gallons.
	7th November	... Inauguration of the "King George the Sixth Reservoir," Staines.
1948 ...	31st March	... Report of the Departmental Committee on Greater London Water Supplies.
1949 ...	Summer	... Drought.
1950 ...	8th June	... Inauguration of the new filter beds at Walton.
1951 ...	4th September	... Inauguration of the "William Girling" reservoir, Chingford.

APPENDIX A

List of Constituent Authorities and their present Representatives

Constituent Authorities	Representatives
Battersea Borough Council	KILOH, R.C., J.P.
Beckenham, Bexley, Bromley, Dartford and Erith Borough Councils, and Chislehurst & Sidcup and Penge Urban District Councils	ALEXANDER, Sir Frank S., Bart., J.P.
Bermondsey Borough Council	ELLIS, W. L. (*Chairman of Water Examination Committee*).
Bethnal Green Borough Council	WILSON, H. P., J.P. (*Chairman of Law and Parliamentary Committee*).
Camberwell Borough Council	BURGESS, Mrs. J., J.P.
Chelsea Borough Council	EDMISTON, G.
Corporation of London	LITTLE, George, J.P. ROBERTSON, Alfred, M.I.Mar.E., M.I.N.A.
Deptford Borough Council	GREEN, W. H., C.B.E., J.P.
Ealing, Acton and Brentford & Chiswick Borough Councils	CLELAND, K. A., J.P.
East Ham County Borough Council	BRADING, C. W., J.P.
Edmonton and Southgate Borough Councils and Enfield Urban District Council	PREYE, W.
Essex County Council	HURST, R. O. C., F.C.S., J.P.
Finsbury Borough Council	ALLEN, C. A., J.P.
Fulham Borough Council	HORTON, J. T.
Greenwich Borough Council	JAQUES, T. P., J.P.
Hackney Borough Council	NICHOLS, W., J.P.
Hammersmith Borough Council	BUCKINGHAM, R. J. (*Chairman of Finance Committee*).
Hampstead Borough Council	CLEAVER, R. J.

Constituent Authorities	Representatives
Hertfordshire County Council	Baxter, E. J., O.B.E., J.P.
Holborn Borough Council	Stallwood, J. C. St. L.
Hornsey and Wood Green Borough Councils	Harrison, A. R., J.P.
Islington Borough Council	Webster, L. R., J.P. (*Chairman of General Purposes Committee*).
Kensington Royal Borough Council	Roots, W. L., B.A.
Kent County Council	Tuff, Major Sir Charles, D.L., J.P.
Kingston-upon-Thames Royal Borough Council, Barnes, Malden & Coombe, Surbiton and Wimbledon Borough Councils and Esher Urban District Council	Hamlin, W. E.
Lambeth Borough Council	Lockyer, W., D.L., J.P.
Lee Conservancy Catchment Board	MacDonnell, J. H.
Lewisham Borough Council	Wells, C. W.
Leyton Borough Council	Evans, D. L., A.M.I.Mech.E., M.Inst.B.E., J.P.
London County Council	Auliff, Mark, J.P.
	Berry, Henry, C.B.E., M.I.Mech.E., A.I.Struct.E., F.R.S.A.
	Brandon, Charles, J.P.
	Cooper, J.
	Doll, Christian C. T., M.A., F.R.I.B.A.
	Falmouth, The Rt. Hon. Viscount
	Guy, W. H.
	Jones, H. R.
	Lucas, J. W. F.
	Newman, Mrs. E. M., O.B.E.
	Pearce, Charles, O.B.E., F.E.I.S., J.P.

Constituent Authorities	Representatives
London County Council —*continued.*	Powe, F. W., J.P. (*Chairman of Advisory Joint Committee*).
	Simmons, C. H., J.P.
	Tipton, F. W.
Middlesex County Council	Clemens, W. R., F.C.A., J.P.
Paddington Borough Council	Robertson, A. G., M.B.E.
Poplar Borough Council	Mills, G. H.
St. Marylebone Borough Council	Timins, Douglas, O.B.E., M.A.
St. Pancras Borough Council	Minter, E. A.
Shoreditch Borough Council	Girling, W. H., O.B.E. (*Chairman of Board*).
Southwark Borough Council	Gibbings, T. G., M.B.E., J.P. (*Chairman of Assessment and Claims Committee*).
Stepney Borough Council	O'Connor, J., J.P.
Stoke Newington Borough Council	Fox, D. F. A.
Surrey County Council	Elliott, F. H., D.L., J.P.
Thames Conservancy	Collard, H. L., O.B.E.
Tottenham Borough Council	Field, E. J.
Twickenham and Heston & Isleworth Borough Councils, and Sunbury-on-Thames Urban District Council	Jamieson, G.
Walthamstow Borough Council	*Vacancy.*
Wandsworth Borough Council	Boniface, W. G.
Wanstead & Woodford and Chingford Borough Councils, and Chigwell and Waltham Holy Cross Urban District Councils	Powell, P. S.
West Ham County Borough Council	Stokes, G. J., J.P.
	Warner, F. A.
Westminster City Council	Rice, W. E., C.B.E., J.P.
	Russell, C. P., J.P.
Willesden Borough Council	Ryde, W. H.
Woolwich Borough Council	Gorman, A. (*Vice-Chairman of Board*).

APPENDIX B

CHIEF OFFICERS

Clerk of the Board

A. B. Pilling, F.C.I.S.	1903–1921
W. Moon (Clerk and Solicitor) (previously Solicitor, 1906–1921).	1921–1922
G. F. Stringer, O.B.E., F.C.I.S., Barrister-at-Law (Clerk and Parliamentary Officer)	1922–1938
R. P. Morgan, F.C.I.S.	1938–1944
C. W. Stoker	1944–1950
W. S. Chevalier	1950–

Chief Engineer

W. B. Bryan, M.I.C.E., M.I.Mech.E.	1904–1914
Sir James Restler, M.I.C.E., M.I.Mech.E.	1914–1918
H. E. Stilgoe, C.B.E., M.I.C.E.	1919–1933
Lt.-Col. Sir Jonathan Davidson, C.M.G., M.Sc., M.I.C.E.	1934–1939
H. F. Cronin, C.B.E., M.C., B.Sc.(Eng.), M.I.C.E. M.I.Mech.E., F.C.G.I.	1939–

Treasurer and Comptroller

F. E. Harris	1904–1908
A. Newton (Accountant)	1908–1922
G. M. Jennings, F.I.M.T.A. (Accountant)	1922–1935
A. V. Huson, F.S.A.A., F.I.M.T.A.	1935–1945
H. Graham, F.S.A.A., F.I.M.T.A., F.S.S., F.R.Econ.S.	1945–

Director of Water Examination

Sir Alexander Houston, K.B.E., C.V.O., M.B., D.Sc., F.R.S.	1905–1933
Lt.-Col. C. H. H. Harold, O.B.E., M.D., Ch.B., D.P.H.	1934–1938
Lt.-Col. E. F. W. Mackenzie, O.B.E., M.C., M.B., Ch.B., D.P.H.	1939–

Solicitor

W. Moon	1906–1922
C. A. Hunt, B.A.	1922–1930
H. A. D. Collins	1930–1940
H. R. McDowell, LL.B.	1940–

(Since 1938 the Solicitor has also held the position of Parliamentary Officer.)

Surveyor

H. Oxley, F.S.I.	1924–1937
C. D. Shott, M.C., F.R.I.C.S., F.A.I.	1937–

APPENDIX C

THE BOARD'S ACTS

Metropolis Water Act, 1902.
Metropolitan Water Board Act, 1906.
Metropolitan Water Board (Charges) Act, 1907.
Metropolitan Water Board (Various Powers) Act, 1907.
Metropolitan Water Board (New Works) Act, 1911.
Metropolitan Water Board Act, 1913.
Metropolitan Water Board Act, 1915.
Metropolitan Water Board (Charges) Act, 1921.
Metropolitan Water Board (Various Powers) Act, 1921.
Metropolitan Water Board Act, 1927.
Metropolitan Water Board Act, 1929.
Metropolitan Water Board Act, 1931.
Metropolitan Water Board Act, 1932.
Metropolitan Water Board Act, 1935.
Ministry of Health Provisional Order Confirmation (Metropolis Water) Act, 1935.
Metropolitan Water Board Act, 1939.
Metropolitan Water Board Act, 1946.

APPENDIX D

ISSUES OF STOCK

THE following schedule gives particulars of the various issues of Stock made by the Board:—

Date of Issue	Description of Stock and purpose of issue	Rate of Int.	Amount of Stock	Terms or price of Issue	Remarks
		%	£		
1st April, 1906	Metropolitan Water (A) Stock 1963–2002, issued in substitution for Irredeemable Debenture Stocks under Section 7 of the Metropolis Water Act, 1902.	3	6,060,165	(*a*)	
22nd July, 1904	First issue of Metropolitan Water (B) Stock, 1934–2003, in part discharge of compensation awarded to the Metropolitan Water Companies other than the New River Company.	3	26,284,609	(*b*)	
21st Oct., 1904	Second issue of Metropolitan Water (B) Stock to provide for expenditure in connection with (1) the discharge of balance of compensation awarded to the Metropolitan Water Companies, (2) the acquisition of the undertakings of the Tottenham and Enfield Urban District Councils and (3) the extension of the Board's undertaking, etc.	3	1,500,000	(*c*) £92 13*s.* 8*d.*	
20th Jan., 1905	Third issue of Metropolitan Water (B) Stock, 1934-2003, in discharge of compensation awarded to the New River Company.	3	6,534,000	(*d*)	
1st May, 1908	Fourth issue of Metropolitan Water (B) Stock to provide for expenditure in connection with the extension of the Board's undertaking.	3	1,500,000	(*c*) £90 2*s.* 6*d.*	
11th Nov., 1919	First issue of Metropolitan Water (C) Stock, 1929-39, for repayment of Money Bills, etc.	5½	2,500,000	£96	Over-subscribed

Date of Issue	Description of Stock and purpose of issue	Rate of Int.	Amount of Stock	Terms or price of Issue	Remarks
		%	£		
10th Nov., 1920	Second issue of Metropolitan Water (C) Stock, 1929-39, for extension of the Board's undertaking.	5½	2,500,000	£92	78% left with underwriters
30th Mar., 1st April, 1931	Metropolitan Water (D) Stock, 1946-66, for conversion of (C) Stock.	4½	3,698,736	(e)	£927,800 allotted to underwriters
17th Nov., 1932	Metropolitan Water (E) Stock, 1953-73, for repayment of Money Bills.	3	2,000,000	£93	87·4% left with underwriters
12th Feb., 1946	Metropolitan Water (F) Stock, 1971-76, for conversion of £2,000,000 (D) Stock, (the balance having been discharged out of Redemption Fund and by borrowing on mortgage, and from internal resources).	2¾	2,000,000	(f) £99	Fully subscribed

NOTES:—

(*a*) Holders of Irredeemable Debenture Stocks of the Metropolitan Water Companies were allotted such an amount of Metropolitan Water (A) Stock as would produce the same income as that derived from their holdings.

(*b*) Issued at the agreed rate of £109 10*s*. 0*d*. Stock for each £100 cash awarded, i.e., equivalent to an issue at £91 6*s*. 6*d*. per cent.

(*c*) Public issue made by tender. This figure represents the average price of the accepted tenders.

(*d*) Award of Court of Arbitration was in terms of Stock and not on a cash basis.

(*e*) £101 (D) Stock for each £100 (C) Stock held.

(*f*) £100 (F) Stock plus £1 cash for each £100 (D) Stock held.

APPENDIX E

SUPPLIES—CONSTANT, METERED AND BULK

I—CONSTANT SUPPLY

When the Board took over in 1904, water was still being distributed on both the intermittent and the constant system. Under the latter the service pipes were constantly charged under pressure, but under the former the water was supplied for a limited period only during each day.

The Metropolis Water Act, 1871, prescribed that every Company should, when required, provide a constant supply of water sufficient for the domestic purposes of the inhabitants, laid on at such pressure as would make the water reach the top storey of the highest houses required to be supplied, but not exceeding the level prescribed by the Company's Special Act.

In the Chelsea, East London, Grand Junction and West Middlesex Companies' areas a constant supply had been given and the prevention of waste was mainly secured by a staff of waste inspectors and the use of Deacon waste meters (see page 199).

In the Kent Company's area all but some 200 houses on Shooter's Hill were similarly supplied and a constant supply was extended to these houses on the completion, in 1911, of a water tower on the summit of the hill.

In the New River Company's area practically all the houses were receiving a constant supply by December, 1904.

The supply to Tottenham and Enfield was included in the Board's New River district with the result that the constant supply percentage of 99.90 for the district was reduced to 91.80 at 1st January, 1905. This figure soon rose to 94.10 and in September, 1907, constant service was extended to Enfield. There now remained only a few houses in the village of Great Amwell to be placed on the system. This was effected in March, 1911.

The percentage of houses on the constant service in the two remaining companies' areas at 31st March, 1905, was, in the Lambeth Company's area, 77.75 and in the Southwark & Vauxhall Company's area, 96.02. At the request of the Barnes Urban District Council the Board undertook to give a constant supply to that district and in December, 1905, the system was extended to Mortlake, Barnes, Sheen and East Sheen. Practically the whole of the Southwark & Vauxhall Company's area was now supplied. In 1905 also, the areas of the two Companies were merged to form the Board's Southern district and by 31st March, 1906, the percentage for the district was 88.24. The Board acquired one of the Crystal Palace tanks in July, 1906, which enabled them to improve the supply to the neighbouring high level districts. In June, 1910, Sydenham, Upper Norwood and Worcester Park came under constant supply. This brought the percentage for the Southern district up to 97.12, and for the Board's area to 99.23.

In February, 1922, the Board at the request of the Surrey County Council extended the system to the Malden & Coombe Urban District. On 1st October, 1926, the Board received a further application from the County Council for a constant supply to the Urban District of Esher and the Dittons. This was afforded as from 1st April, 1927.

II—METERED SUPPLIES

The Board supply water for non-domestic purposes through meters, of which there are now nearly 32,000. Available statistics of this supply go back to the year ending 31st March, 1912, and the daily average supply afforded through meters since then is shown on the graph opposite page 141.

This supply has increased with remarkable steadiness, unlike the unmetered supply, afforded mainly to the domestic household, which has gone up in waves during the same period.

An interesting point of similarity in the progress of the metered and unmetered supplies is that during the first world war both supplies went up fairly steadily, whereas during the second world war on the whole both declined. The metered supply in the pre-war peak year of 1938–39 amounted to 34,662 million gallons (95 million gallons a day). In the year ending 31st March, 1949, it reached 35,407 million gallons (97 millions gallons a day). In 1951–52 it was 37,985 million gallons (104 million gallons a day).

The increased relative importance of the metered supply is brought out by the fact that in 1911–12, when the total daily average supply to the Board's direct area stood at 243 million gallons, the metered supply, 56 million gallons, was only about 23 per cent. of the total, whereas, in the year 1951–52, when the supply to the direct area was 316 million gallons, the metered supply was 104 million gallons which is only a little under 33 per cent. In the same year (1951–52) the combined supply to the direct area from the Lee and from the Board's springs and wells was 32.3 per cent. of the total. In other words the metered supply alone exceeded that from these combined sources.

The metered supply includes all leakage, waste, etc., on the consumer's side of the meter. The unmetered supply, however, includes all the losses by leakage, including those from the Board's mains, and a number of non-domestic uses of water such as fire fighting, garden watering, private motor-car washing, etc. It is interesting to note that the unmetered supply, though erratic, has shown a substantially lower trend of increase than the metered supply. The daily average metered supply in 1951-52 of 104 million gallons showed a percentage increase of 86 since 1911–12. The unmetered supply (212 million gallons) showed a percentage increase of just over 13.

Although thousands of new premises have been constructed since the war, all with modern water-using facilities, the unmetered supply declined from 1947–48 to 1950–51. It rose slightly in 1951–52. The amount used for domestic consumption was possibly kept down by the shortage and high price of fuel and to some extent by publicity, but the Board's drive on waste has substantially contributed to the fall. The results have also been assisted

by weather conditions, i.e., mild winters and, with the exception of 1949, poor summers.

The following table, which sets out the supply to the direct area, etc., and the population at census years, reveals some interesting facts.

Year	Population	Average daily supply.					
		Direct Area.		Unmetered.		Metered.	
		Total m.g.	Gallons per head.	Total m.g.	Gallons per head.	Total m.g.	Gallons per head.
1911–12 ...	6,600,000	243	37	187	28	56	9
1921–22 ...	6,800,000	248	36	187	27	61	9
1931–32 ...	7,000,000	277	39	199	28	78	11
1951–52 ...	6,400,000	316	49	212	33	104	16
Difference between 1911–12 and 1951–52.	− 200,000	+ 73	+ 12	+ 25	+ 5	+ 48	+ 7

It will be seen that although the overall consumption has increased by 12 gallons per head per day (i.e. from 37 to 49), the unmetered consumption has only increased by 5 gallons per head per day.

The population also has decreased slightly since 1911–12 and substantially since 1931–32.

The metered supply is not distributed evenly over the Board's area. By turning to the outline map at page 44, one can see the Board's area at 1903 which has not changed substantially since. In the year 1951–52 the Central and Eastern area had a daily average metered consumption of 41 million gallons, the Western area 32 millions, the Southern 19 millions and the Kent 12 millions.

The income from revenue meters for the year ended 31st December, 1951, amounted to just under £2,500,000, whilst the total revenue was just over £8,700,000. The importance of the metered supply as a source of income is therefore clear.

There are many large single supplies with average daily consumptions exceeding ½ million gallons, the largest approaching 1½ million gallons per day.

When it is realised that the average daily supplies to Ilfracombe and Clacton amount to about 600,000 and 1,026,000 gallons, while those of Stratford-upon-Avon and Winchester are 820,000 and 1,261,000 gallons, the magnitude of these trade supplies will be appreciated.

III—BULK SUPPLIES

The Board's powers to supply water in bulk, apart from the general authority of the Water Act, 1945, are contained in the provisions of the East London Waterworks Act, 1900, the Metropolis Water Act, 1902, and the Board's Acts of 1907, 1927 and 1935. Only the more important supplies afforded under these powers are noted in this present account.

Section 13(1) of the Metropolis Water Act, 1902, provides that the Board shall supply water in bulk, if required, to the Boroughs of Croydon and Richmond, the Urban Districts of Cheshunt and Ware, and to any Rural District wholly or partly within the Board's limits.

An agreement was concluded in 1904 with the Richmond Corporation under this Act, no limit being placed on the amount to be supplied. The charge for the supply was 2d. per thousand gallons for the first 75 million gallons and 6d. per thousand gallons for any excess, subject to a minimum payment of £1,000 per annum. The charges have been reviewed periodically and are now:—5d. per thousand gallons, first 75 m.g.; 1s. 1d. per thousand gallons, next 100 m.g.; 1s. 3d. per thousand gallons, over 175 m.g.

Croydon Corporation went to arbitration, as provided in the 1902 Act, and by an award made on 26th February, 1904, the Board were required to supply up to a maximum of 500 million gallons in any year, subject to a charge of $2\frac{1}{8}$d. per thousand gallons.

The supply was to be delivered under the following reservoir heads and in the proportions indicated:— Selhurst 5/10, Norwood 3/10, Rockhill 2/10.

Negotiations in 1920 for revising the terms of the award fell through and the Croydon Corporation promoted a Bill in 1921 seeking authority to acquire the Board's Selhurst well and works and to re-open certain terms of the award. The Board petitioned against this Bill, but after further negotiations their opposition was withdrawn. The following terms were agreed :—

(1) The Board to sell to the Corporation the Selhurst well for £100,000 ; (2) the intermittent bulk supply to Croydon to be a constant supply; (3) the price for the bulk supply to be revised, subject to further revision in 5 years, by the Ministry of Health on the application of either party.

The Board subsequently agreed to afford the Corporation a bulk supply not exceeding 500 million gallons in any year ending 31st December, at a price of $4\frac{3}{4}$d. per thousand gallons. This charge has been varied since and now stands at $5\frac{1}{4}$d. per thousand gallons.

A bulk supply afforded to the undertaking of the Cheshunt Urban District Council by the East London Waterworks was continued by the Board under the Metropolis Water Act, 1902, the terms being settled by arbitration in 1913. The undertaking itself, however, was taken over by the Board under the Metropolitan Water Board Act, 1927.

By the Metropolitan Water Board Act of 1927, the Board are empowered to afford a bulk supply outside their limits of supply on such terms and for such period as might be agreed upon, provided that this does not interfere with the supply of water within the Board's limits.

Scheduled to this Act is an Agreement dated 21st March, 1927, and made between the Board and the Barnet District Water Company, which pro-

vides for a supply to the Company not exceeding 6 million gallons a day at 10½d. or 1s. per thousand gallons, according to the point of delivery.

On 15th March, 1928, the Board agreed, under their 1927 Act, to afford a bulk supply to the Colne Valley Water Company, starting in 1930. The quantity in the first instance was limited to two million gallons a day, rising during the following ten years to a maximum of five million gallons a day. The price was fixed at 1s. per thousand gallons subject to periodical revision. The present price is 1s. 7d. per thousand gallons. The Company are to determine the agreement as from 31st December, 1953.

In April, 1929, the Board agreed to afford a temporary bulk supply to the South Essex Waterworks Company limited to half a million gallons a day during that year but increasing to one million gallons a day in 1930 and to one and a half million gallons a day in 1931. The cost was 1s. 3d. per thousand gallons. The supply was discontinued in 1932. In 1950, at the request of the Company, the Board again agreed to provide a temporary bulk supply. This supply was discontinued in the same year.

In the 1929–30 session of Parliament, Croydon Corporation sought power to execute waterworks, to purchase the Board's Merton Abbey well and to sink a new well at Keston. The Board opposed the last two suggestions and offered as an alternative a further bulk supply. An agreement, completed in 1930, provided for a supply by the Board under their 1927 Act, at 10½d per thousand gallons, the water to be delivered under Selhurst reservoir pressure. This was in addition to the 500 million gallons per annum included in the Award of the Court of Arbitration.

This agreement was superseded by a further agreement scheduled to the Board's 1935 Act whereby the supply was to rank with the Board's general supply and not to be subject to the restriction contained in the Board's 1927 Act. The supply was to be afforded under the heads of the Selhurst, Norwood and Rockhill reservoirs. The maximum daily quantities and the present prices are set out below:—

Reservoir head.	*Maximum daily quantity.*	*Price per 1,000 galls.*
Selhurst ...	¾ m.g.	1s. 5½d.
Norwood ...	1 ,,	1s. 8d.
Rockhill ...	½ ,,	1s. 10½d.

In September, 1931, an agreement was reached with the Sutton District Water Company, also under the 1927 Act, for a supply ranging between half a million and 3 million gallons a day, at a price of one shilling per thousand gallons. This supply was discontinued in 1943, but a small quantity was afforded in 1949.

In the 1933–34 session of Parliament, the South West Suburban Water Company promoted a Bill to enable them to take an additional average daily quantity of 2½ million gallons from the Thames. The Board opposed this Bill on the ground that it would affect the quantity which they were entitled to take from the Thames. An agreement was, therefore, made on 27th April, 1934, between the Board and the Company which provided for a supply in bulk not exceeding ½ million gallons per day until 30th March,

1940, and thereafter not exceeding an average of 5 million gallons a day in any one year, or a maximum of 7 million gallons in any one day. The agreed price was 8⅞d. (now 1s. 2¼d.) per thousand gallons plus a quarterly payment rising to £2,500 by 1st April, 1940, in respect of Capital works.

The amount of water supplied in bulk has increased considerably since the war. Up to 31st March, 1938, it exceeded an average of three million gallons a day only in the year 1931–32 when the South Essex Waterworks Company took a large temporary supply. Since the war, however, the average daily supply has been as high as 7·9 million gallons (in the year 1948–49) and has only fallen below an average of six million gallons a day in the year 1951–52 (5·7 million gallons). The two largest supplies are those afforded to the Croydon Corporation and the South West Suburban Water Company. The average daily supply to the Corporation has not been below 1,800,000 gallons since 1946–47, whilst that to the Company has always exceeded 2,200,000 gallons since 1943–44. The year of highest "take" by the Croydon Corporation was 1949–50 when a daily average supply of nearly 3 million gallons was afforded. The year of highest "take" by the Company was 1947–48, when the bulk supply averaged nearly 3 1/3 million gallons a day.

Very nearly all the water supplied in bulk comes from the Thames. Bulk supplies from wells are very small and the Lee has only been used on two occasions.

The proportion of water supplied in bulk to the total supply is small. It has never exceeded 2·42 per cent., which it attained in the year 1949–50, and was never over 1 per cent. before the year 1930–31.

The total quantity of water supplied in bulk by the Board during the year 1951–52 was derived and distributed as follows:—

	Total in thousand gallons.
Barnet District Water Company, from the Thames ...	253,624
Croydon Corporation, from the Thames	691,026
Richmond Corporation, from the Thames	305,900
South-West Suburban Water Company, from the Thames	821,101
Sevenoaks Rural District Council, from Wells	161
Total	2,071,812

APPENDIX F

SUMMARY OF GENERAL INFORMATION

AREA

Statutory Area	576 square miles
Area directly supplied	540 „ „

POPULATION

Population directly supplied (approximate)	6,500,000

SUPPLY

(Figures relate to the year 1951/52)

Average daily supply:

To Board's area of direct supply	316·3 million gallons
To adjacent undertakings in bulk	5·7 „ „
Total supplied by Board	322·0 „ „

(Thames, 68%; Lee, 17%; Wells, 15%)

Supply per head per day to Board's consumers:	*Gallons*	*Per cent.*
Domestic (unmetered)	33	67
Trade (metered)	16	33
Total	49	100

FUEL CONSUMED, 1951/52

Coal and Coke	116,427 tons
Fuel Oil	1,150,577 gallons
Electricity	49,742,000 units

APPENDIX G

STATEMENT SHOWING DEVELOPMENT OF THE UNDERTAKING

	April, 1905	*April*, 1952
Storage, balancing and subsidence reservoirs, for unfiltered water	43	49
Acreage	1,261·3	3,356·4
Capacity (million gallons)	7,346·7	27,267·5
Service reservoirs and suction tanks, for filtered water	76	91
Capacity (million gallons)	243·0	262·9
Filter beds (slow sand)	137	165
Acreage	140	163·3
Filter beds (primary)	—	95
Area (square feet)	—	74,544
Mechanical filters	—	12
Area (square feet)	—	640
Engines	252	295
Horse power	33,726	66,460
Mains (miles)	5,920	8,513

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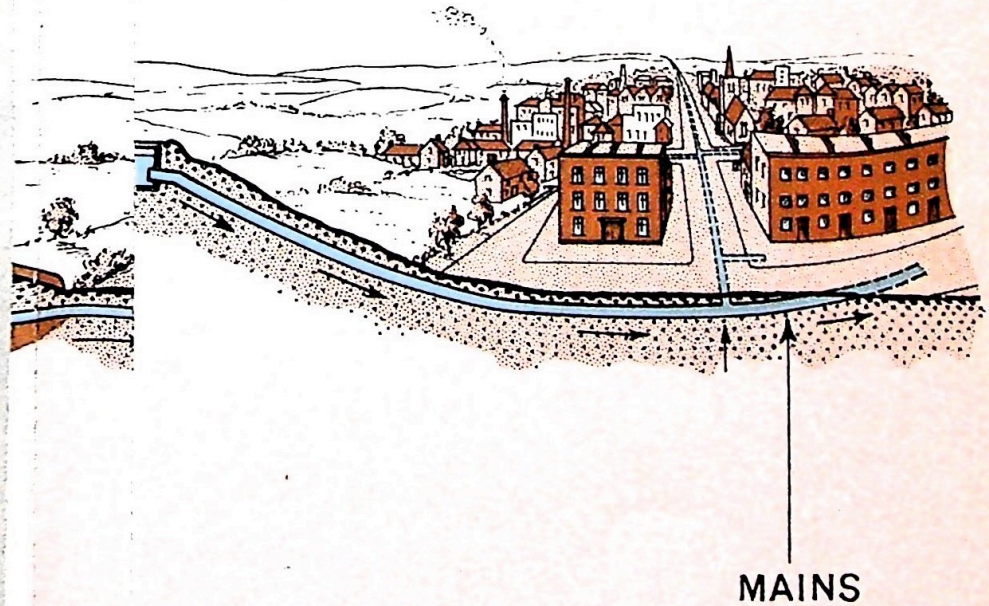
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